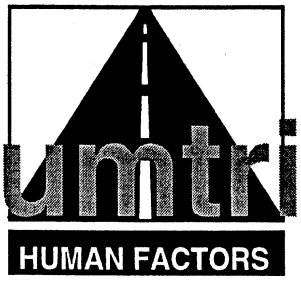
echnical Report UMTRI-97-22 June, 1997

uence of Warning Message Content on Message Understandability and When Drivers Respond

Dan Damouth and Paul Green



UMTRI The University of Michigan Transportation Research Institute

Transportation Research Institute

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-97-22		

4. Title and Subtitle	5. Report Date
Influence of Warning Message Content on Message Understandability and When Drivers Respond	June, 1997
	6. Performing Organization Code: account 375136
7. Author(s): Daniel Damouth and Paul Green	8. Performing Organization Report No.: UMTRI-97-22
9. Performing Organization Name and Address: The University of Michigan Transportation Research Institute (UMTRI) 2901 Baxter Rd, Ann Arbor, Michigan 48109-2150	10. Work Unit no. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Volvo Car Company, Ergonomics Center Dept. 98260, PVD 4:2, S-405 08 Goteborg, Sweden	13. Type of Report and Period Covered: 1/97-4/97 14. Sponsoring Agency Code
15. Supplementary Notes	

The purpose of this project is to (1) evaluate the understandability of warnings and messages being considered for future Volvo products, and (2) determine the characteristics that lead to understandable (and complied with) warnings. Fifty U.S. drivers operated a driving simulator while 29 warning messages were presented on a center console CRT (e.g., "Throttle fault, service ASAP") one at a time. In response to each message, drivers said what they thought was wrong and what they would do about it (e.g., slow down, stop at the next service station, call on cellular phone for help, look in the manual). Subsequently, drivers completed several questionnaires concerning factors such as the drivability and risk of accident associated with the problems mentioned in the messages. Finally, drivers were asked to rank order a set of action phrases (e.g. service immediately, service soon) by how long they would wait before following it.

Messages that were not well understood by drivers included "fan fault," "airdistr fault," "rear backrest unlocked," "filler door ajar," "a/c switched off-engine temp high," "throttle fault," "wheel spin," "skid control temp disabled," and "road grip exceeded." Often, messages were not understood because drivers were unfamiliar with the function described. (What is the throttle? What is the filler door?). Recommended alternative messages were provided in almost every case, even where messages were reasonably well understood, to improve consistency and the timeliness of driver responses.

In addition, an equation was developed that predicted when drivers would respond to a warning. Key factors in the equation where the drivability of the vehicle after the warning, the risk of a crash if the warning is ignored, the perceived urgency of the action phrase, and if drivers could fix the indicated malfunction themselves.

17. Key Words	18. Distribution Statement
ITS, human factors, ergonomics, driving, warnings, usability, safety	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classify. (of this report)	20. Security Classify. (of this page)	21. No. of pages	22. Price
none	none	81	

Influence of Warning Message Content on Message Understandability and When Drivers Respond

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UMTRI Technical Report 97-22

1 ISSUES

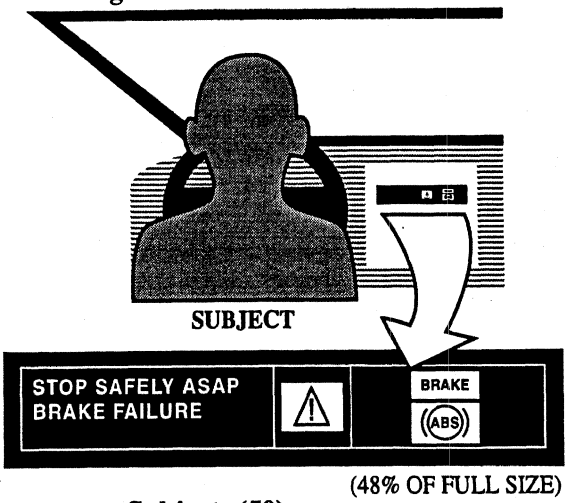
1. Do drivers understand warnings that may appear in future vehicles?
2. What do drivers say they will do when the messages are presented?
3. What characteristics of warnings lead to an immediate driver response?

2 METHOD

Complete 3 Tasks

1 In driving simulator:	Read 29 warnings one at a time. Determine what is wrong. What would you do and when? (Experimenter records subject responses.)
2 Out of simulator:	Fill out questionnaires relating to Drivability, Accident Risk, Risk and Cost of Further Damage, and Fixability after each warning appears (see description below for specific coding).
3 Out of simulator:	Rank 21 action phrases ("service soon," "service now," etc.) from most to least urgent.

Driving Simulator Scenario



(48% OF FULL SIZE)

Subjects (50)

Age	Men	Women
25-35	13	12
55-65	12	13

3 RESULTS

When? category = 2.701 + 0.453 (drivability) + 0.200 (risk of accident) - 0.044 (action phrase ranking) - 0.103 (fixability)

VARIABLE	DESCRIPTION	CODING
When? category	Driver will respond...	4=immediately, 3=soon, 2=after trip, 1=eventually, 0=never
Drivability	After the warning the car is...	3=not drivable, 2=somewhat, 1=normal
Risk of accident	If the warning is not heeded, the risk is...	3=high, 2=some, 1=none
Risk of further damage	If the warning is not heeded, the risk is...	3=high, 2=some, 1=none
Fixability	Can the driver fix the problem without assistance...	1=definitely, 2=probably, 3=don't know, 4=probably not, 5=definitely not
Cost	Cost of further damage is...	4=extreme, 3=high, 2=medium, 1=small
Action phrase rank	Ranked value of phrase in message...	range of 1-21, 1=most urgent

4 RECOMMENDATIONS

Original Message	Possible Alternative	Why
Air bag fault A See manual		S, TA
Stop safely ASAP Air bag fault	Air bag fault Stop safely ASAP	CF
Air bag fault Call service shop	Air bag fault Call for service	CE
Safety system 12 Fault service	Safety system 12 Fault — Service	C, CF, S, TA
Drive slowly Engine fault A	Engine fault A Drive slowly	CF, S, TA
Trans fault A Service ASAP		S, TA
Stop safely ASAP Oil press loss	Oil press loss Stop safely ASAP	CF
Stop engine Check oil level		S, 1
Service required Emission syst C	Emission syst C Service required	CF, S, TA
Slow down Trans high temp	High trans temp Slow down	CF
Stop safely ASAP Engine temp high	High engine temp Stop safely ASAP	CF
Engine temp high Let engine cool	High engine temp Let engine cool	CF
Throttle fault Service ASAP	Accelrator fault Service ASAP	U, 2
Engine fault D Fix next service		S, TA

Original Message	Possible Alternative	Why
Stop safely ASAP Brake failure	Brake failure Stop safely ASAP	CF
Brake failure Call service shop	Brake failure Call for service	CE, CF
Airdistr fault Service required	Heat airflow Fault — Service	U
A/C switched off Engine temp high	A/C off due to high engine temp	U
Rear left door ajar	Rear left door is open	CE
Fan fault, see owner manual	Vent fan fault See manual	U, 3
Bulb failure, turn indicator	Bulb failure turn signal	CE
Filler door ajar	Gas tank door is open	U
Rear backrest unlocked	Back seat is unlocked	U
Wheel spin	Almost skidding Slow down	U
Shift slower Trans damage	May damage trans Shift slower	CF, S
Do not shift at high rev	Do not shift at high rev	CF
Road grip exceeded	Skidding Slow down	PG, U
Skid control temp disabled	Skid control off Slow down	CF, U, 4

Problem/Relevant Criteria

C Continuation of phrase
CE Common English
CF Consistent Format
PG Positive Guidance
S Specificity
TA Too Ambiguous, e.g.,: "Fault A"
U Understanding

Message Specific Notes

1 Is oil low? dirty?
2 To fit, accelerator is misspelled
3 Engine or climate fan?
4 "Temp" = temperature?
Poor understanding of skid control

See the full report for details concerning each message and the evaluation criteria. The actual messages are all upper case but are shown in mixed case here to save space.

PREFACE

This report examines both a specific set of messages intended for future Volvo products that may be marketed in the U.S., and in a larger sense, attempts to determine:

- what qualities of messages make them understandable, and
- what about a message leads a driver to treat the warning as urgent.

This information should lead to future message sets that are understandable and elicit driver responses that are as the designers had intended. Volvo has long recognized that developing safe vehicles involves more than the technical performance of the equipment, but designing the equipment in a manner that drivers can understand how to use it properly.

Readers should note that the warning messages are shown in a variety of places in this report. When shown in pictures of the interface, text is in upper case as it would be in the actual application. When shown as text, lower case is used to enhance readability.

The authors would like to thank several individuals for their contributions to this research.

Anders Hallen (Volvo - Sweden)	for helping with the arrangements for this project
Jaap Maartense (Nedcar - Netherlands)	for serving as the project liaison

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INTRODUCTION

Motor vehicles have come a long way from the days when there were only two warning lights on the instrument panel: one for when the engine temperature was too high; a second for when the oil pressure was too low. Warnings can help drivers determine if the vehicle may fail (such as the case for oil or engine temperature), if routine maintenance is required, if safety systems are failing (such as brakes), and can provide other types of information. This information can help assure that the vehicle is operated safely, economically, and comfortably.

To be useful and usable by drivers, not only must sensors, processors, and displays be reliable, but the information presented to drivers must also be understandable. Messages can either be presented as symbols (Green, 1993) or words. This study was conducted to support Volvo's efforts to develop a text-based status and warning system for future motor vehicles. More specifically, the general purpose of this project was to:

- Evaluate the understandability of warnings and messages being considered for future Volvo products and
- Determine the characteristics that lead to understandable and complied with warnings.

The specific issues of interest are listed below.

- How well do drivers understand the 29 sample messages for warning, control, and chassis functions that may be presented on the advanced information display?
- What do drivers say they will do when the messages are presented?
- What characteristics of warnings lead to an immediate driver response?
- What kinds of warnings, in general, are drivers likely to understand?

While the literature on warnings is vast (Miller and Lehto, 1986; Laughery, Wogalter, and Young, 1994), the research pertinent to this set of questions, especially in the automotive literature, is limited (e.g., Green, 1995; Hoekstra, Williams, and Green, 1993).

In terms of applications to computer systems, a useful synopsis of the design guidelines for messages appears in Schneiderman (1982). He identifies four characteristics of a good message.

Characteristic	Explanation
specificity	A good message will say exactly what is wrong. So, a poor message would be "syntax error," while "unmatched left parenthesis" with a pointer to the error would be much more informative.
constructive guidance and positive tone	A good error message should say what to do.
user-centered phrasing	A good error message should make it clear the user is in control, not the system. This point is less important than the previous two points.
appropriate physical format	A good message should make judicious use of upper case, reserving all upper case for only the most serious errors. In a motor vehicle, only upper case is sometimes available for text displays.

Several studies specifically consider warning messages in motor vehicles. Green (1984) had 66 licensed drivers varying in age serve as subjects. Drivers sat in a mockup of a vehicle and were shown slides of image clusters in the location where these images would normally appear. Elements shown included a digital speedometer, gauges for fuel, engine temperature, oil pressure, and electrical system voltage, along with several warning lights. Across slides, the design of the warning gauges (digital versus analog, use of color coding and marking, etc.) varied. Drivers were told to imagine they were driving from Ann Arbor to Detroit. In response to slides presented

on the instrument panel, drivers said what was wrong and what they would do about it. Response options are shown in Table 1 below.

Table 1. Options from Green (1984).

When	What
now	ignore it
	speed up
	slow down
	keep checking to see if it gets worse
	stop immediately and wait for help
	stop immediately and fix it yourself
	turn around and go home
soon	stop at the next service station
	get off at the next exit and fix it yourself
eventually	stop at a service station when you get back
	stop at a service station before the next trip
	fix it yourself when you get back
	fix it yourself before the next trip
	mention it to a mechanic the next time you have the car repaired
	tell a friend or relative about it
special case	special case

In addition to obtaining data on driver understanding of various gauge formats, information was also obtained on driver knowledge of their own vehicles and vehicles in general. At the time, digital displays for many functions were being considered, some of which required drivers to know vehicle characteristics in detail. So, for example, displaying the engine temperature as "212 deg. F" with no other supporting information, would require the driver to know the exact normal and abnormal operating temperatures. As shown by the examples in Appendix A, facts of this type are generally not known by drivers with any accuracy.

This study makes several key points.

1. The structured response set method utilized was readily implemented and drivers were able to provide responses with minimal difficulty. Further use of this method is encouraged.

2. It is important to make the simulation quite realistic if managers and engineers not familiar with human factors are to believe the results. The original plan called for subjects to sit in a chair and view slides on a screen. While the use of a mockup elevated the cost of the study, it was clear from reactions of engineers during tours and presentation, that the use of the buck made the results more believable. For this reason, use of a mockup or simulator in message understanding studies is highly desired.

3. Drivers know very little about the inner workings of vehicles and have little sense of what representative values are for operating parameters.

In another study to develop methods for evaluating in-vehicle warnings and evaluate candidates, Green, 1996 (see also Williams, Hoekstra, and Green, 1993) conducted three experiments. In the first experiment, 27 drivers were asked questions that examined their knowledge of vehicle components. ("What happens if the anti lock brakes do not work?") Appendix A summarizes driver responses from best to least understood. On average, only 39 percent (10.4/27) of the responses were correct, suggesting that drivers did not have detailed technical knowledge of motor

vehicles. This makes it a challenge to create warning messages to which drivers will respond appropriately.

There seems to be no clear pattern with regard to driver understanding of systems. For example, understanding of what made anti lock brakes unique was in the top third, understanding of the consequences of a failure was in the middle of the list, and knowledge of the catalytic converter was in the bottom third. On the other hand, drivers were much better at responding to symptoms (e.g., the steering fluid is low) than describing the purpose of components (e.g., what does the catalytic converter do?).

The second experiment in Green (1996) demonstrated the value of the population stereotype method for generating warning text and developed warnings for numerous functions. This method allowed drivers to select from a wide variety of alternatives very quickly. Drivers selected text from columns that could be strung together to form a message. For example, in Table 2, choices for a drive belt warning could be "accessory drive belt," "replace accessory drive belt," "accessory drive belt service needed," or many other choices. The values in the table indicated the number of drivers (out of 60) who selected a particular word. Readers interested in the counts for each message should see the original paper. An important realization was that every possible warning did not have to be examined. For example, the warnings for low coolant, low washer fluid, low power steering fluid, and all other fluid warnings should be worded in a similar manner.

Table 2. Preferences for accessory drive belt warning structure.

30	(None)	**accessory drive belt**		15	service	19	(none)
25	Replace			14	loose or worn	16	needed
4	New			12	maintenance	16	required
1	*Check*			11	(none)	8	necessary
				8	repair	1	desired

Note: "Check," shown in italics, was not shown on the original form but was written in by a subject.

In the third experiment, understandability of 15 warnings by 20 drivers was examined. The method was similar to that used by Green (1984). The most important misunderstandings were interpreting brake failure warnings (indicating diminished performance) as brake failure indicators (no brakes).

Thus, the literature suggests the following:

- For creating messages, the population stereotype method is a reasonable method of developing alternatives.
- For examining message understanding, the "what would you do" approach of Green (1984) seems reasonable. In conducting such studies, providing a mockup helps to convince designers that the results are applicable to real interfaces.
- Drivers generally do not know much about the vehicles they drive. When given a description of a problem, drivers are more likely to know what to do when the symptom is described, than when told a particular component is failing.

Although the literature provides some sense of the knowledge drivers have of cars, it does not provide enough insight to predict if the proposed messages would be understood. Also, beyond generalities, the literature provides little insight as to how drivers would respond to warning messages and why.

TEST PLAN

Test Participants

Fifty licensed drivers were recruited from several sources, including an advertisement in the local newspaper, lists of potential and previous subjects maintained by UMTRI, posters at a local Volvo dealer, and word of mouth. Since the results were intended to be applied to future Volvo products, initially only owners of Volvos and competitive products (BMW, Lexus, etc.) were recruited, a constraint that proved to be infeasible within the limits of the project schedule and budget. Where possible, owners of newer and more expensive cars were recruited. (See Appendix B for a list of their vehicles.) That recruitment effort met with success as 17 out of the 50 subjects had cell phones, often the case for owners of more expensive cars. (For the U.S., the market penetration is between 5 and 10 percent.) Further, 19 subjects reported they drove a vehicle with some type of text-based warning system.

As shown in Table 3, the sample was composed of an almost equal number of men and women drawn from the young and older age groups.

Table 3. Subject age.

	Men	Women
Young (25-35)	n=13 (25-35, mean=29)	n=12 (27-35, mean=31)
Older (55-65)	n=12 (56-65, mean=61)	n=13 (57-65, mean=62)

Due to problems with the equipment, subjects' vision was not measured. However, the test procedure involved subjects reading each message aloud for the experimenter to hear, and no apparent legibility problems occurred. Further, since all drivers were licensed and therefore likely to have had a screening eye exam, all drivers were assumed to have at least 20/40 corrected vision. Subjects reportedly drove 1000 miles to 30,000 miles per year with a mean of 12813 miles (20616 km), which is fairly typical of U.S. drivers. Among the older drivers, men reported a significantly higher annual mileage than women ($p<.05$) with a difference in means of 7275 miles (11640 km).

Subjects represented a wide variety of technical backgrounds (teacher, postal worker, homemaker, nuclear engineer, engraver, etc.). While there were some students in the younger age group, except for two computer science majors, they all were from different programs.

Subjects were computer savvy and all but two were native English speakers. All were fluent in English. Within each age-sex group, 3/4 of the subjects reported they used computers daily except for the older men, where only 3 of the 12 reported daily use. In contrast, 23 of the subjects had changed the oil themselves (indicating some knowledge of motor vehicles), but only four subjects subscribed to or sometimes read a car magazine (such as Automobile or Car & Driver), suggesting there were few car aficionados in the sample. Normative data for Volvo drivers for these characteristics are lacking.

Warnings

The messages examined were from a large set that may appear in future Volvo products. A total of 29 warning messages provided by Volvo were evaluated. Figure 1 shows the complete list of warnings.

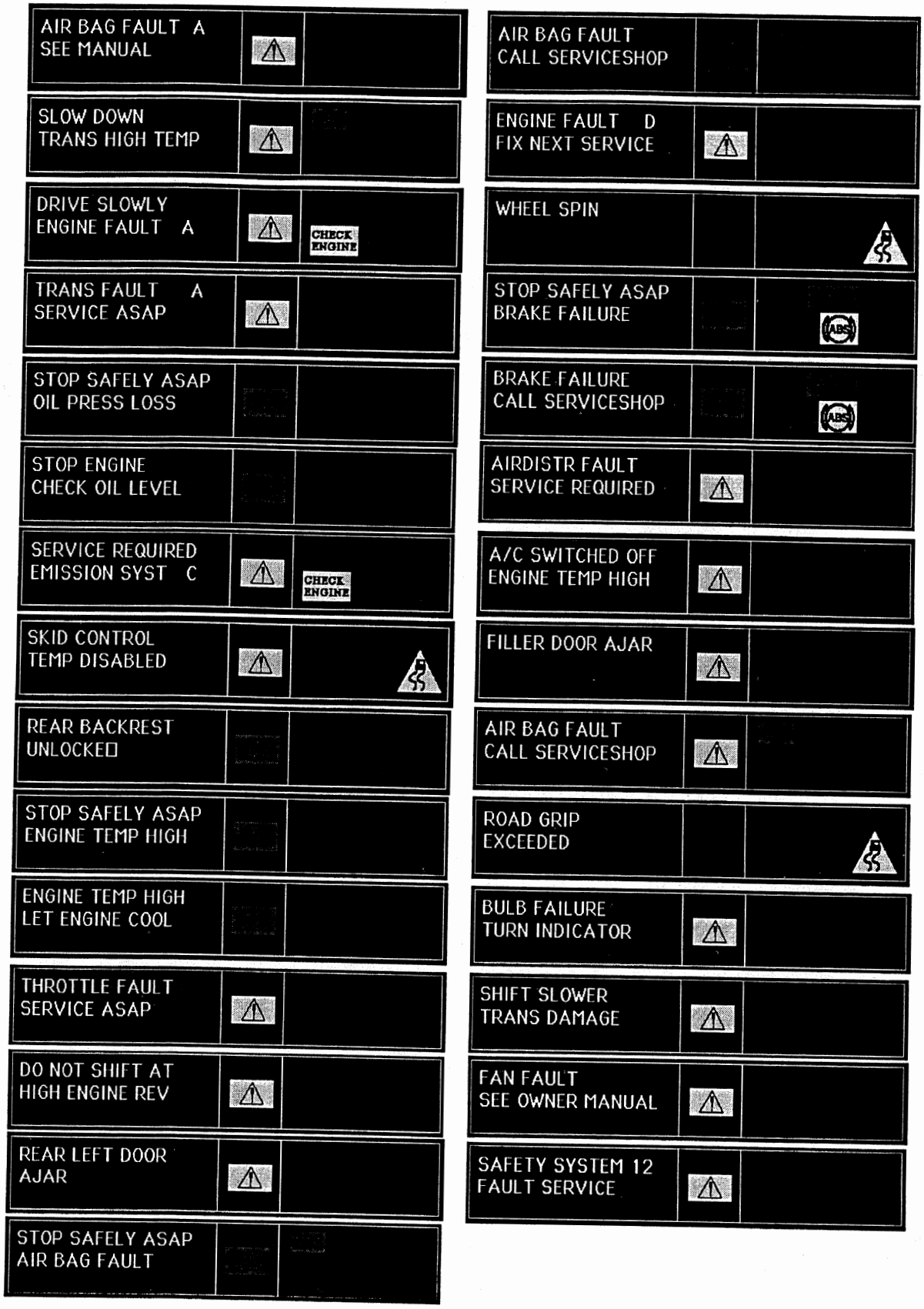


Figure 1. Complete sample of warning messages

Figure 2 shows a full size representation of one warning presented to subjects. The character height on the display used in the experiment was 6 millimeters (versus 5.6 in the intended application). Each message consisted of two lines of text of up to 16 5x7 sans-serif dot matrix characters, and any relevant symbols. In contrast, in the intended application, the text will be shown on display located in the lower left-hand part of the speedometer/tachometer cluster. The yellow or red general warning light will appear in the center of the console between the speedometer and the tachometer. The associated warning symbols will appear to the right of the cluster. For the purposes of this particular experiment, the warning was presented as a single unified display to reduce prototyping time and cost. Differences in understandability of the two implementations of the warning set are likely to be small. The lighting conditions are listed in Appendix C.

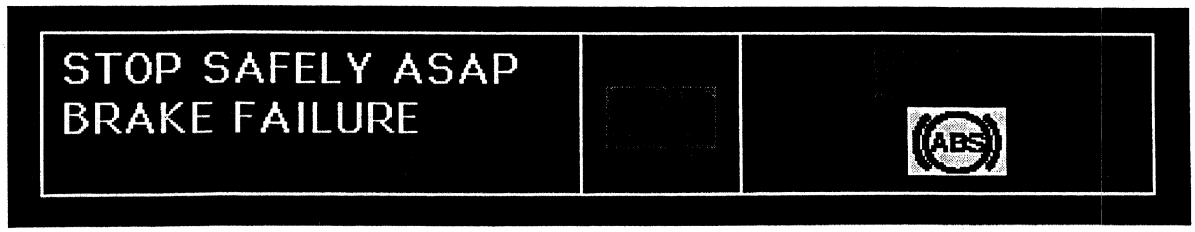
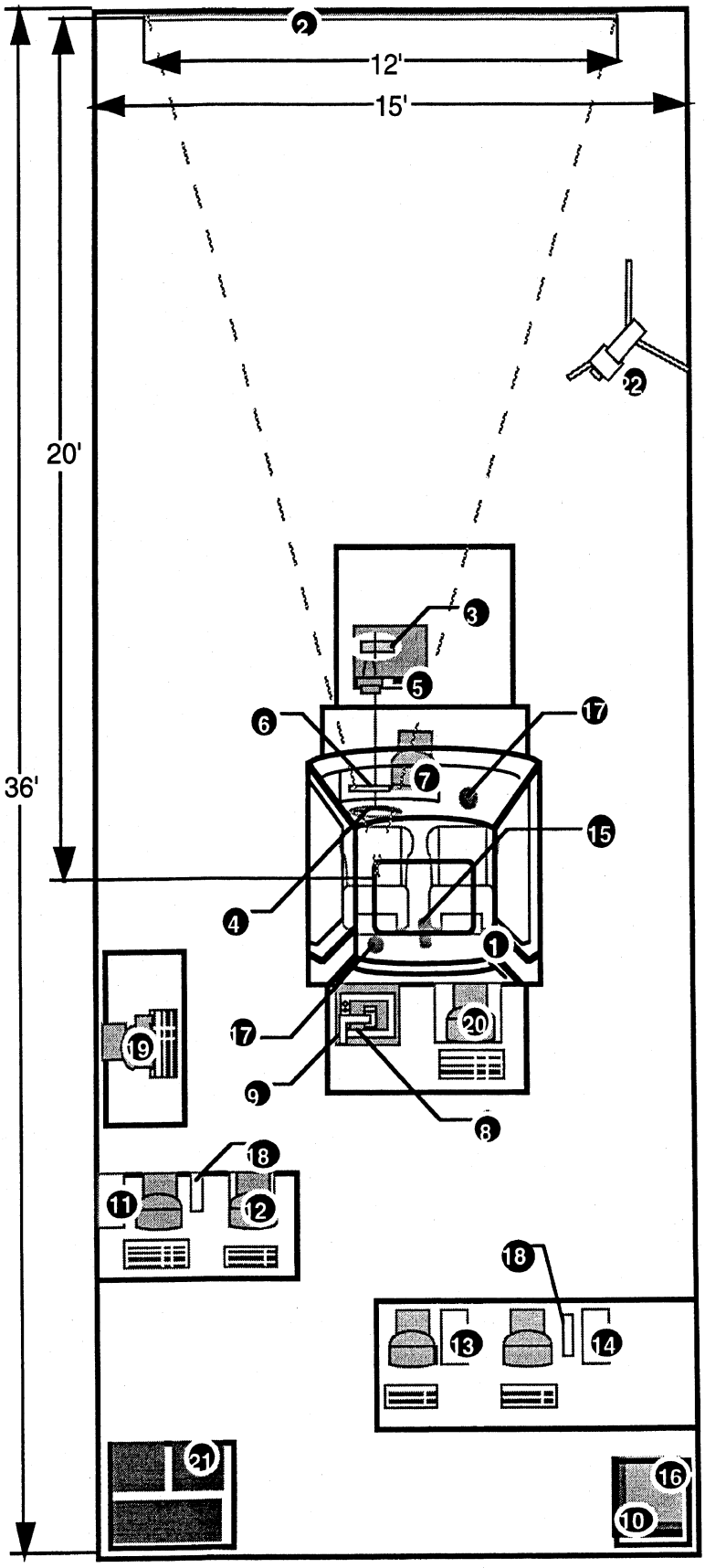


Figure 2. An example warning message with symbols.
(In this example, the general warning and brake warning symbols
are red, the ABS symbol is yellow.)

A program was developed in SuperCard to show the messages on a CRT on the console of the UMTRI driving simulator. The size of the text and symbols was designed to be the same from the perspective of the driver as in the proposed Volvo system. The program allowed the experimenter to present the warnings one at a time (including going backward through the list) along with associated tones.

Driving Simulator

To provide the desired context, this experiment was conducted using the UMTRI Driver Interface Research Simulator, a low-cost driving simulator based on a network of Macintosh computers (MacAdam, Green, and Reed, 1993; Green and Olson, 1997; Olson and Green, 1997). The simulator (Figure 3) consists of an A-to-B pillar mockup of a car, a projection screen, a torque motor connected to the steering wheel, a sound system (to provide engine, drive train, tire, and wind noise), a computer system to project images of an instrument panel, and other hardware. The projection screen, offering a 30 degree field of view, was 20 feet (7.3 m) in front of the driver, effectively at optical infinity. Warnings were shown on a Macintosh 13-inch color monitor located in the center of the center console. The monitor was fitted with an ELO Touch Systems Intellitouch interface.



1. 1985 Chrysler Laser mockup with simulated hood
2. 8'X10' projection screen with 3M hi-white encapsulated reflective sheeting
3. PMI Motion Technologies ServoDisk DC motor (model 00-01602-002 type U16M4) with Copley Controls Corp. controller (model 413) and power supply (model 645)
4. 3-spoke steering wheel
5. Sharp color LCD projection system (model XG-E850U)
6. 4"X13" plexiglas screen
7. ELO Touch Systems Intellitouch monitor (model E284A-1345)
8. Sharp computer projection panel (model QA-1650)
9. 3M overhead projector (model 9550)
10. Kenwood stereo cassette deck (model KX-48C), stereo graphics equalizer (model GE-7030), and AM-FM stereo receiver (model KRA-4080)
11. Power Macintosh 9500/200
12. Power Macintosh 7100/80AV
13. Power Macintosh 8500/120
14. Macintosh Quadra 840AV
15. Panasonic GP-KS152 "lipstick" Camera
16. Alpine MRV-T300 Amplifier
17. Aura AST-1B-4 Bass Shakers
18. Bernoulli Mac Transporter 230-MB drive
19. Dell OptiPlex 486 GXM 5166
20. Macintosh Quadra 700
21. Video recording system
22. Panasonic WV-BP510 low level light camera

Figure 3. Plan view of the driving simulator facility.

The simulated road was flat, with a few gentle curves, and no other vehicles. Occasional 55-mph speed limit signs were alongside the road, and small posts were placed on the outside of turns.

Driver facial expressions were recorded by a small hidden camera facing the subject. A lipstick camera mounted over the subject's right shoulder recorded the warning display on the center console. Comments were recorded by miniature microphones, one on the A-pillar and a second near the inside mirror location. The output of the two cameras, the computer-generated speedometer/tachometer cluster, and the road scene were recorded using a quad-split image on video tape and displayed on monitors in the video rack (Appendix D). Figure 4 shows a sample of the recorded material.

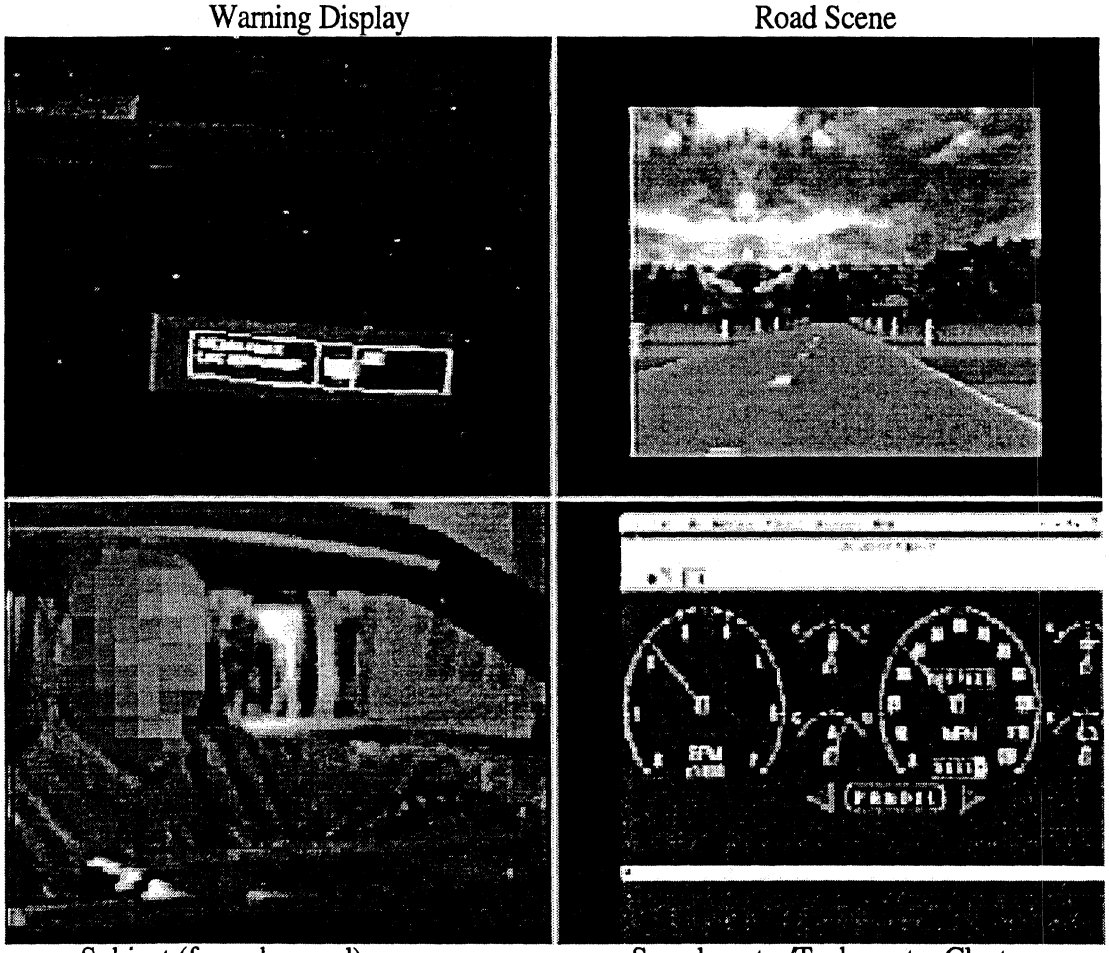


Figure 4. Typical recorded image

In addition to the simulator, a Titmus model OV-7M Vision Tester was used to check visual acuity of the subjects.

Test Activities and Their Sequence

Each experiment was begun by giving the subject a brief overview of the focus of the study and generally what they were going to do. (See Appendix E for the exact instructions.) The subject then signed a consent form (Appendix F) and filled out a biographical form (Appendix G). The subject was put in the driving simulator and given the following scenario to imagine:

"I'd like you to pretend you are driving by yourself in your 1-year-old car to visit a friend in East Lansing, one hour away. It's a somewhat rainy afternoon and you are driving on the expressway. You just left your home in Ann Arbor 15 minutes ago. Your car has a cell phone and a driver's manual."

The subject was then told that a text message and symbols would periodically appear on the display on the dashboard, and an example (not used in the experiment) was shown. The subject was instructed to read each message aloud (to verify that they had read it properly), and then to tell the experimenter two things:

1. What they would do in response to the message; and,
2. What they thought might be wrong with the car, if anything, that was causing the message to appear.

The subject practiced driving for a few minutes before the first message appeared. The subject's words were typed into a Microsoft Word document by an experimenter. Initially, Word was running on a Macintosh Duo, later, a Dell 486 clone. If the subject did not read the message aloud, or did not answer both questions, they were prompted by the experimenter. If an answer was vague or hard to interpret, then the experimenter asked clarifying questions (such as, "what do you mean by 'soon'?"). The experimenter was trying to determine (1) what the primary response would be, (2) when the response would occur, (3) whether or not the driver followed any action phrase in the message, and (4) whether or not the driver understood the message.

Messages were presented one at a time in the same order for all subjects. The order was generally constructed so that messages involving the same system (e.g., air bags) were not close to one another. There were four exceptions. These message "pairs" consisting of an initial message and a follow-up message to be displayed after the driver had stopped the car in response to the initial message.

After the simulator run, the subject was brought into a conference room and asked to fill out four questionnaires (Appendices H, I, J, K) regarding their understanding and interpretation of the problems mentioned in the warning messages (e.g., "engine fault d"). Specifically, these forms examined if subjects believed the vehicle would remain drivable after the warning appeared, if the warning concerned an accident-provocative fault, the risk of further noncrash damage indicated by the warning, and if the driver could fix the malfunction. The forms were designed to be as self-explanatory as possible, but verbal reinforcement was used if subjects were uncertain what a question was asking.

Table 4 presents the questions examined and the responses provided.

Table 4. Questionnaire content.

Questionnaire	Description	Choices
drivability	How drivable is the car assuming there are no symptoms other than the warning message?	not drivable somewhat drivable normal don't know
risk of accident	Risk of a crash because of this problem if the problem is uncorrected.	high risk some risk none don't know
risk of further damage	Risk of further damage if the problem is not corrected assuming a crash does not occur.	high risk some risk none don't know
fixability	Is the driver able to fix it without assistance?	definitely probably don't know / maybe probably not definitely not
cost of further damage	Damage resulting if the problem is not corrected assuming a crash does not occur.	extreme (> $3000) high ($1000 - $3000) medium ($300 - $700) small (< $100)

Not all the messages are represented in the questionnaires. In some cases messages did not contain a problem component (e.g., "do not shift at high rev"). Messages judged less interesting (e.g., "bulb failure") were also excluded to reduce the overall duration of the questionnaire period, bordering on excessively lengthy.

All questionnaires were multiple choice. Subjects were instructed to circle one answer for each problem. For example, in the "risk of accident" questionnaire, subjects were asked to evaluate the chance that the given problem (e.g., "throttle fault") would cause an accident if not fixed. The data collected was intended to help understand the connection between warning content and driver responses to them.

Next, the subject was given a set of cards, each of which had a phrase from a potential warning message that either told the driver to do something, or implied that something needed to be done. (See Table 5.) The list was constructed from terms in the message set plus other that have appeared in warning systems elsewhere or could appear. Generally, long messages were not included in the set evaluated because they would not fit in the limited display space available and would take drivers too long to read.

Table 5. Message action phrases (listed in a random order).

#	Action Phrases	In Volvo Set?	Comment
1	call serviceshop	y	
2	contact dealer	n	used in other Volvo messages
3	drive slowly	y	
4	fix next service	y	
5	see manual	y	
6	service	y	sometimes without modifier
7	service ASAP	y	
8	service at once	n	
9	service eventually	n	
10	service immediately	n	
11	service imperative	n	
12	service necessary	n	
13	service needed	y	
14	service now	n	
15	service promptly	n	
16	service pronto	n	
17	service required	y	
18	service shortly	n	
19	service soon	n	
20	service urgent	n	
21	slow down	y	
22	stop safely ASAP	y	

Note: In the message set originally proposed by Volvo, "serviceshop" is one word.

The subject was asked to rank the cards according to how soon he/she would do the needed action and then assign groups of cards to categories (Table 6). The purpose of this task was to determine the relative urgency drivers associated with terms that might be used in warning messages. This is to overcome mismatches in perceived urgency between message designers and ordinary drivers.

Table 6. Categories used in sorting message urgency.

Category	Explanation (on card)
Now	while driving or stop on road
Soon	next service station
After trip	or before next trip
Eventually	next scheduled service or when weather improves
Never	or do nothing

Finally, the subject was paid $15. Any questions the subjects had were answered before they departed.

RESULTS

As noted above, the data that was collected for each subject was of four types: (1) biographical information such as age, sex, occupation, type of car driven, etc. (summarized in the Test Participants section), (2) simulator data (responses and interpretations of messages), (3) questionnaire data (concerning drivability, the risk of further damage, etc. influence decisions), and (4) rank ordering of action phrases from messages.

Simulator Data

The simulator transcripts were coded using a template (Table 7). For each subject and message, a primary response and a time of response were identified. For the 15 messages with an action phrase, whether or not subjects followed the phrase was recorded. The other 14 messages, indicated by "n/a" in column 3 of Table 7, either contained no action phrase or merely said that service was needed. For 10 of the messages, it was determined whether or not subjects understood the text. Responses to the other 20 messages (indicated by "n/a" in column 4 of Table 7) lacked clear markings with which to assess specific understanding, though they were evaluated qualitatively. In some cases, common misconceptions of the messages were also recorded. For example, in the case of "rear backrest unlocked" references to the front seat or something being broken were noted.

Table 7. Data coding template.

2. Time of response (Immediately, Soon, After trip, Eventually, Never)

3. Did they follow the directive? (Yes, No, Unclear)

1. Primary response (Manual, Diagnose, Fix personally, Get help, Change driving, Stop, Do nothing)

4. Did they understand the message? (0= they said "I don't know what that means.")

Message	1	2	3	4	Code If Not Understood
Air bag fault A, see manual				n/a	
Slow down, trans high temp				n/a	
Drive slowly, engine fault A				n/a	
Trans fault A, service ASAP			n/a	n/a	
Stop safely ASAP, oil press loss				n/a	
Stop engine, check oil level				n/a	
Service required, emission syst C			n/a	n/a	
Skid control temp disabled			n/a		know what it means?
Rear backrest unlocked			n/a		1=back seat only, 2=front mentioned, 3=broken, 4=other
Stop safely ASAP, engine temp high				n/a	
Engine temp high, let engine cool				n/a	
Throttle fault, service ASAP			n/a		know what the throttle does?
Do not shift at high rev				n/a	
Rear left door ajar			n/a		know what 'ajar' meant?
Stop safely ASAP, air bag fault				n/a	
Air bag fault, call serviceshop				n/a	
Engine fault D, fix next service			n/a	n/a	
Wheel spin			n/a		1=tires only, 2=mention steering wheel, 3=car problem, 4=other
Stop safely ASAP, brake failure				n/a	
Brake failure, call serviceshop				n/a	
Airdistr fault, service required			n/a		1=compartment only, 2=engine mentioned, 3=filter
A/C switched off, engine temp high			n/a		1=A/C problem,2 =turn on A/C, 3=understand, 4=other
Filler door ajar			n/a		2=initially didn't know but guessed it later
Air bag fault, call serviceshop				n/a	
Road grip exceeded			n/a		don't know what happened?
Bulb failure, turn indicator			n/a	n/a	
Shift slower, trans damage				n/a	
Fan fault, see owner manual					1=pass. compart. only, 2=engine/belt mentioned, 3=other
Safety system 12, fault service			n/a	n/a	

What did drivers say they would do in response to the messages?

Driver responses to warnings were categorized by the experimenter as subjects responded to messages. Table 8 shows the codes used for the primary response.

Table 8. Primary response codes.

Category Name	Description
Change driving	Used if the driver's main or only response was to change the way he/she was driving. Examples include slowing down and being more careful when shifting.
Do nothing	The driver ignored the message with no plans to repair the item mentioned.
Diagnose car	The driver examined the car to try to get more information about the problem. The most common instance of this was looking under the hood for broken lines or low fluid. This code was used when the driver's response would be determined largely by the result of the diagnosis. Thus, if a subject said he/she would look under the hood but also said he/she would call for help in any case, "Get help" rather than "Diagnose car" was considered the primary response.
Fix by self	The driver said he/she would fix the problem personally.
Get help	The driver would obtain advice/help/repair from some knowledgeable source. This included calling a service station, dealer, or knowledgeable friend as well as taking the car in to a shop.
Read manual	The driver would look in the manual and base further actions on what it said. Thus, if a subject would look in the manual, but take the car in for repair regardless of what it said, "Get help" was considered the primary response.
Stop and wait	The driver would stop the car and wait; usually, either for engine temperature to go down, or for the message to go away.
Missing data	The primary response could not be determined from the driver's words (e.g., the driver could not decide what to do within the time given (roughly a minute), and the driver gave contradictory or ambiguous responses).

Using the codes in Table 8, the primary responses of drivers to each message were identified. Table 9 provides a summary of how often each type of response occurred as a function of driver age and sex. The most common response was "get help" (34 percent of the responses), followed by "read the manual" (24 percent). The only age or sex differences evident are that men were less likely to get help than women, more likely to diagnose the car, and slightly more likely to fix the problem themselves ($p<.05$). This follows conventional stereotypes in the U.S. for male-female differences.

Table 9. Frequency of primary responses split by age and sex.

	Women (n=25)		Men (n=25)		
Response	Older	Young	Older	Young	Total
change driving	24	34	19	42	119
do nothing	6	17	7	17	47
diagnose car	31	20	58	37	146
fix by self	35	42	42	53	172
get help	164	124	113	100	501
read manual	86	84	81	95	346
stop and wait	19	20	15	26	80
missing data	12	7	13	7	39
Total	377	348	348	377	1450

A more detailed listing of the data (by message, listed alphabetically), appears in Table 10. Messages annotated with "2" appear after the car has stopped in response to another message. Drivers did not always say they would stop in response to the first message, which is why there is more missing data for the secondary messages than for others.

Table 10. Primary response.

Problem Name	Change driving	Do nothing	Diagnose car	Fix by self	Get help	Missing data	Read manual	Stop and wait	Total
a/c switched off, engine temp high	3	11	11	1	10	1	7	6	50
air bag fault A, see manual	0	2	0	0	16	0	32	0	50
air bag fault, call serviceshop	0	0	1	3	35	0	11	0	50
air bag fault, call serviceshop (2)	0	0	1	1	30	11	7	0	50
airdistr fault, service required	0	0	2	4	26	2	16	0	50
brake failure, call serviceshop (2)	0	0	3	0	40	3	4	0	50
bulb failure, turn indicator	1	0	1	30	16	1	1	0	50
do not shift at high rev	22	7	0	0	4	8	9	0	50
drive slowly, engine fault A	1	0	8	0	16	0	25	0	50
engine fault D, fix next service	0	0	0	1	36	0	13	0	50
engine temp high, let engine cool (2)	0	0	16	2	7	1	4	20	50
fan fault, see owner manual	0	0	6	0	3	1	40	0	50
filler door ajar	0	2	1	32	2	0	13	0	50
rear backrest unlocked	0	5	1	28	5	2	9	0	50
rear left door ajar	0	0	0	50	0	0	0	0	50
road grip exceeded	32	5	0	0	0	2	10	1	50
safety system 12, fault service	0	1	0	0	8	0	41	0	50
service required, emission syst C	0	0	0	1	33	0	16	0	50
shift slower, trans damage	14	0	3	0	28	1	4	0	50
skid control temp disabled	12	8	1	2	15	1	10	1	50
slow down, trans high temp	8	0	9	0	17	0	10	6	50
stop engine, check oil level (2)	0	0	30	14	4	1	1	0	50
stop safely ASAP, air bag fault	0	1	1	1	19	0	22	6	50
stop safely ASAP, brake failure	0	0	6	0	28	0	8	8	50
stop safely ASAP, engine temp high	0	0	18	1	9	1	1	20	50
stop safely ASAP, oil press loss	0	0	14	1	23	0	2	10	50
throttle fault, service ASAP	0	0	6	0	33	1	10	0	50
trans fault A, service ASAP	0	0	5	0	34	0	11	0	50
wheel spin	26	5	2	0	4	2	9	2	50
Total	119	47	146	172	501	39	346	80	1450

In this table and all subsequent tables of responses, the cell entries correspond to the number of subjects responding in a particular manner. Since there were exactly 50 subjects, the percentage of subjects responding in a particular manner is double the cell entry value (e.g., 22 percent of drivers elected to do nothing upon seeing the message "A/C SWITCHED OFF, ENGINE TEMP HIGH"). In many cases, the responses listed were not mutually exclusive; for example, drivers often slowed down after any message, but that was not always considered a primary response.

As shown in the table, there were many message-specific variations in how drivers responded. For example, there were four messages that indicated the driver should stop safely ASAP. However, the percentage of drivers whose primary response would be to stop and wait varied from 12 to 40 percent. Additional information on driver responses to specific messages appears later in this section.

How soon would drivers act on the messages?

The timing of driver reactions was associated with the categories shown in Table 11. Table 12 shows the frequency with which those categories were selected by driver age and sex for the 29 messages examined. The most common response was to act on the warning immediately, a response chosen about half of the time. Very few drivers completely ignored warnings. Young drivers waited significantly longer to deal with car problems than older drivers ($p<.01$). In contrast to the data on response action, there were no gender differences.

Table 11. Categories for when the primary response would occur.

Category	Description
Immediately	right away, instantly
Soon	within 10-15 minutes or so; next service station or exit
After trip	within a few hours to a day or so; after arrival at destination or home
Eventually	weeks or months, when weather improves, when funds are sufficient, or next normally scheduled service
Never	driver would not do anything

Table 12. Effect of age and sex on when drivers would deal with warnings.

	Women (n=25)		Men (n=25)		
Response	Older	Young	Older	Young	Total
After trip	78	81	91	99	349
Eventually	13	13	7	28	61
Immediately	214	186	183	190	773
Missing data	14	8	13	8	43
Never	6	17	7	17	47
Soon	52	43	47	35	177
Total	377	348	348	377	1450

Table 13 shows when drivers would respond to each message (the timing of the primary response). In contrast to what drivers would do, when drivers would respond was fairly consistent within groups of similarly worded messages. For example, for all four stop safely ASAP messages, almost all drivers would do something immediately.

Table 13. Time of primary response.

Response	Eventually Never		Soon After Trip		Immediately	Total
A/C switched off, engine temp high	11	2	9	6	21	49
Air bag fault A, see manual	2	2	26	3	16	49
Air bag fault, call serviceshop	0	5	25	4	16	50
Air bag fault, call serviceshop (2)	0	1	4	2	32	39
Airdistr fault, service required	0	7	24	4	12	47
Brake failure, call serviceshop (2)	0	0	0	1	46	47
Bulb failure, turn indicator	0	7	32	5	3	47
Do not shift at high rev	7	0	4	4	27	42
Drive slowly, engine fault A	0	1	3	9	37	50
Engine fault D, fix next service	0	19	21	7	3	50
Engine temp high, let engine cool	0	0	1	4	44	49
Fan fault, see owner manual	0	3	19	6	21	49
Filler door ajar	2	0	21	7	20	50
Rear backrest unlocked	5	1	20	6	16	48
Rear left door ajar	0	0	12	6	32	50
Road grip exceeded	5	0	3	0	40	48
Safety system 12, fault service	1	1	21	6	21	50
Service required, emission syst C	0	6	29	11	4	50
Shift slower, trans damage	0	1	19	7	22	49
Skid control temp disabled	8	3	14	4	20	49
Slow down, trans high temp	0	0	3	18	29	50
Stop engine, check oil level	0	0	0	6	43	49
Stop safely ASAP, air bag fault	1	1	10	2	36	50
Stop safely ASAP, brake failure	0	0	0	3	47	50
Stop safely ASAP, engine temp high	0	0	0	3	46	49
Stop safely ASAP, oil press loss	0	0	0	3	47	50
Throttle fault, service ASAP	0	0	18	18	13	49
Trans fault A, service ASAP	0	1	7	19	23	50
Wheel spin	5	0	4	3	36	48
Total Count	47	61	349	177	773	1407

Would drivers comply with the warnings?

For each message, actions drivers said they would carry out were recorded. Missing data was most commonly due to the subject not seeing the message or due to the difficulty in determining the answer. Overall compliance was fairly high, just under 90 percent, with women being a few percent more compliant than men.

Table 14 shows the compliance data for each message. In general, compliance was highest for actions the driver would do immediately (e.g., "slow down") than for activities that might occur later (e.g., "call serviceshop," "see manual"). Compliance was also lower for warnings related to

the air bags. Many drivers did not consider the air bag very important and said they could do without them. As a result, they saw no danger in driving after an air bag fault had been reported.

Table 14. Number of subjects who followed the directive in each message.

Message	Yes	No	Missing Data
slow down, trans high temp	50	0	0
engine temp high, let engine cool (2)	48	1	1
stop engine, check oil level (2)	48	1	1
brake failure, call serviceshop (2)	45	2	3
stop safely ASAP, engine temp high	48	2	0
drive slowly, engine fault A	46	3	1
stop safely ASAP, oil press loss	47	3	0
shift slower, trans damage	44	4	2
fan fault, see owner manual	44	5	1
stop safely ASAP, brake failure	45	5	0
do not shift at high rev	37	5	8
air bag fault, call serviceshop (2)	33	6	11
air bag fault, call serviceshop	42	8	0
stop safely ASAP, air bag fault	37	13	0
air bag fault A, see manual	33	17	0
Total	647	75	28

This view is exemplified in one subject's response to "stop safely ASAP, air bag fault:"

> *"Well, I'm not going to stop out here in the middle of the road. Hopefully I won't be in an accident where I need to use my airbag, so, in fact I'll just wait till I get home."*

Another group of subjects viewed airbags with skepticism, as was the case with one subject responding to "air bag fault, see manual:"

> *"I would assume that it's just reporting that I disabled the damn thing, because I don't like the damn things. I would do nothing about it."*

Still others viewed the entire text warning system with skepticism, and tended to view most warnings concerning air bags or any system as possible computer errors rather than "real" problems. The following were responses to "drive slowly, engine fault:"

> *"I'd slow down. if it stayed on, I would pull over and get out, turn the engine off and check it, see if it went off. It doesn't appear by the wording to be a major problem. Seems like I could still drive it. On my Mustang, the check engine light came on all the time, so after a while I wasn't heeding it much."*

> *"I had a new car that had 'check engine' on for weeks because of a bad computer part. I would read the manual the next time I stopped. If it was under warranty I would get it fixed. Probably just ignore it if it wasn't under warranty."*

This phenomenon was particularly evident in the driving simulator, because the messages were unaccompanied by any other symptoms (such as sounds, smells, or changes in car performance).

Did drivers understand the messages, and if not, why?

Most messages were well understood. Messages where understanding was imperfect are listed in Table 15 in order of decreasing understandability, along the number of drivers who did not understand each message and the reasons why. There are wide variations in the data with 49 out of 50 drivers understanding the rear door ajar message but only 5 out of 50 drivers understanding the fan fault message. Missing data in that table refers to cases where it could not be determined from the driver's response if a message was understood.

Table 15. Understandability of messages.

Message	Understood	Missing	Did Not Understand	Reason Not Understood Subjects ...
rear left door ajar	49	0	1	did not understand the word "ajar"
road grip exceeded	38	0	12	said they "don't know" what the message concerns
skid control temp disabled	36	1	13	said they "don't know" what the message concerns
wheel spin	35 (mentioned tires only)	1	7	said they "don't know" what the message concerns
			6	think it might mean the steering wheel
			1	think something is broken
throttle fault, service ASAP	30	5	15	did not know what throttle was
a/c switched off, engine temp high	22	8	6	said they "don't know" what the message concerns
			3	think the A/C has a problem
			8	think they should turn the air conditioner on
			3	-other-
filler door ajar	19	0	15	"don't know"
			16	initially did not know what it meant but guessed later
rear backrest unlocked	16 (only back seat mentioned)	1	14	said they "don't know" what the message concerns
			10	mentioned the front seat
			7	think something is wrong with the car
			2	-other-
airdistr fault, service required	14 (only AC or vent fan mentioned)	6	16	said they "don't know" what the message concerns
			11	mentioned the engine
			3	-other-
fan fault, see manual	5 (only AC or vent fan mentioned)	0	6	said they "don't know" what the message concerns
			38	mentioned the engine or belt
			1	-other-

ROAD GRIP EXCEEDED

The most common type of response by someone who did not understand this message was similar to the following excerpt:

> *"road grip exceeded. I don't know what that means. I guess I would pull off, stop, start up again and see if it flashed again. If it did, and I didn't know what it means, I would get to a gas station again and see if someone could help me. That's a term I don't know."*

The responses were difficult to code because many subjects expressed some uncertainty about the message, even if they clearly guessed that it had to do with the wheels spinning and losing traction. For example:

> *"Road grip exceeded. Um. Road grip exceeded. I don't know what that means, if it's referring to the tires gripping the road, or if I'm going too fast for the conditions. I don't know what that means. I would make sure I was driving safely."*

WHEEL SPIN

Subjects had the same general uncertainties about this message as with ROAD GRIP EXCEEDED, with the additional problem that some of them thought the message might be referring to the steering wheel:

> *"Wheel spin -- something flashed and disappeared, I think it was yellow -- [I have] no idea, but if it meant that my steering wheel was spinning, I would know that... could be the tires. I don't see how the tires could spin."*

Although no quantitative measure was made, a significant fraction of subjects did not get a clear glimpse of the spinning car symbol that accompanied this message, because it flashed twice and then disappeared. Some subjects noted that the display was not in the center of the field of view, making it more difficult to pay attention to the message and drive at the same time.

THROTTLE FAULT, SERVICE ASAP

Most commonly, subjects simply did not know what a throttle was:

> *"Throttle fault, service ASAP. I dunno what that is, so I'd continue along, and maybe look it up later, and then decide what to do."*

A/C SWITCHED OFF, ENGINE TEMP HIGH

There were a variety of interesting responses to this message, ranging from perfect understanding to total bewilderment. Most of the subjects who did not understand the message did not know why the A/C and engine temperature were mentioned in the same message:

> *"A/C switched off, engine temp high. I don't really know what the A/C has to do with the engine temp. I would think that the computer is giving me 2 different messages accidentally. I would think that depending on the climate control in the car there might be a chance that A/C switched off might mean I'm trying to do something impossible, so I would turn it off. Engine temp high, I would think perhaps it's a radiator problem. Depending on how hot it seemed in the car I would*

believe that this was an erroneous message. Hmm, maybe A/C means alternating current."

"A/C switched off, engine temp high. I don't know how the two go together. Anytime the engine is high, you want to slow down or stop, you know, find out why. I think with the A/C on you get that fan on a consistent basis, so maybe you could cool it down a bit by turning the A/C on, but I don't know why you get both at once in this message."

"A/C switched off, engine temp high -- pull over and look at the manual, because I have no idea why those two things are connected. I thought the A/C made the engine hotter, I didn't think it had anything to do with cooling your engine."

Several subjects thought that "A/C switched off" was supposed to be a problem rather than a report of what the car had done. Naturally, this confused the subjects who understood the relationship between the A/C and engine temperature:

"A/C switched off, engine temp high. That doesn't make sense because the A/C usually creates heat. I'd check the temp gauges. If it's a hot day, I'd turn the heat on, because that usually cools off the engine. I would slow down, again look at the gauges, pull over, check to make sure I have sufficient water in the radiator. That message is not worded right. I'd pull into the next service station I came across to get it checked out."

Others thought they were supposed to turn the A/C on:

"A/C switched off, engine temp high. Engine temp is high. I don't know if it wants me to switch off the A/C or switch it on. I would check the manual within the next 20 minutes and follow the instructions."

Some subjects thought there was a problem with the A/C unit:

A/C switched off, engine temp high. We're not running the A/C and the temp is high anyway. I'd stop and let things cool down, and get to a service station to see if my A/C needed coolant, or what. To get someone to look at the A/C unit."

FILLER DOOR AJAR

Men had higher initial rates of understanding for this message (64 percent of the men versus 12 percent of the women). After thinking about the message, about 70 percent of the sample understood it, and the gender differences became small. The main problem was that drivers did not know what a filler door was.

"Filler door ajar. I have no idea what a filler door is. I would ignore it. In Lansing I would open and shut all my doors to make sure I shut them good. And I would ask whoever I was visiting if they knew what a filler door was, and if they didn't I would look it up in the book."

"Filler door ajar. Filler for what? Gas, window washer, oil, transmission fluid? umm. If it's trans fluid or oil, it's a problem. If it's that little door over the gas cap it's not so serious. It doesn't really tell you which. I guess I might pull over. Then I would check anything that had a door in which someone could be poured in it. Radiator, windshield washer, trans fluid, oil. I can't think of anything else that has a filler."

There were 16 additional subjects who didn't understand the message initially, but then guessed that it meant the gas tank filler door:

"Filler door ajar. I don't know what a filler door is. Let me think for a minute what a filler door is. Oh. I guess that would probably mean the gas tank door is ajar. Whenever I stopped, where I was going, I'd check the door."

"Filler door ajar -- I'd pull over and check the manual, because I have no idea what a filler door is. Oh, maybe that means the gas cap; but I'd have to look at the manual."

"Filler door ajar. Well, if I knew what my filler door was, I'd stop and close it. [10 seconds of silence]. Oh, if it's my gas pump, I'd probably just let it go until I stop normally."

"Filler door .. what? ajar. I don't know what a filler door is, unless it's like, the gas thing. I dunno.. If I knew what it was, I'd probably pull over and adjust it, but if I didn't, I'd probably just keep driving."

REAR BACKREST UNLOCKED

A number of subjects said they did not know what "rear backrest" referred to:

"Rear backrest unlocked. Hmm, rear backrest. I would probably ignore that. I don't know what it means, but it doesn't sound very important."

"Rear backrest unlocked. I wouldn't worry about that at all. I'd have it checked when I got back to Ann Arbor. If I had passengers, I'd take it into a dealer in Ann Arbor, but otherwise I'd continue and have it checked in Ann Arbor. Quite frankly I've never even heard of a rear backrest, or why it would be unlocked. I might get the manual out in Lansing and read about it in there. Might be able to figure it out."

Some subjects thought it might refer to something in the front seat area:

"Rear backrest unlocked. I assume it's my own backrest that's unlocked. I would pull over, get out, check my seat back. I wouldn't want to be driving and have the seat move on me."

"Rear backrest unlocked. Hmm. (pause) That would not be anything drastic, I'd probably wait until after the trip to do anything. Could be a pin got worn and something came loose. I don't know whether they're talking about the main seat or something in the back seat. iI it's the back, I wouldn't worry about it but if it's my seat I'd worry because I have to lean on it. if it's my seat I'd get it taken care of right away, but otherwise I'd wait till I got back to Ann Arbor."

As two of the excerpts above show, some subjects thought the message might mean something was broken. For this particular message there was no visual reference for the subject as the cab extended only from the A- to the B- pillar. (There was no back seat.)

AIRDISTR FAULT, SERVICE REQUIRED

The largest group of subjects said they did not know what was wrong, even if they guessed that AIRDISTR referred to the air distributor:

"Air distr fault, service required. Hmm... I think I'd probably, I don't even know what an air distr is. If the car was running OK, I'd go to Lansing. Get it looked at in Ann Arbor the next day."

"Air distr fault, service required. The next time I got it serviced normally, I'd have it checked out. Something to do with the engine, but I don't know exactly what. Air distribution...distributor."

Eleven subjects thought it might refer to the air distribution in the engine.

FAN FAULT, SEE OWNER MANUAL

Subjects generally thought that "fan fault" might refer to the fan belt or something in the engine area. Only five subjects were confident it was something in the passenger compartment.

SHIFT SLOWER, TRANS DAMAGE and DO NOT SHIFT AT HIGH ENGINE REV

These messages were not evaluated quantitatively for understanding because it was too difficult to interpret what drivers said. For example:

"Shift slower, trans damage. I'd be gingerly when I changed gears, and I'd also take it in at the next service shop, and find out if it needs to be fixed right away. Guess the clutch is going."

"Shift slower, trans damage. I'd have to be more careful shifting. Could be low trans fluid, or something more tragically wrong. If the fluid didn't fix it, I'd have to take it to a dealer and have it checked."

"Do not shift at high rev. I would heed that warning. I dunno what caused the message, I wouldn't know."

When drivers were asked to say in more detail what they meant by being "gingerly" with the gears, or being more "careful" when shifting, they had trouble. It was clear, however, that many drivers did not know how to interpret the messages:

"Do not shift at high engine rev. What is the message trying to tell me? don't shift up, or don't shift down? It may be a comment on how I'm driving. Maybe saying don't shift when you're redline. I don't even know how high a rev it considers a high rev."

"Do not shift at high rev. Don't shift into low? Is that what it means? There's some problem with the gears."

Some subjects realized that context, such as whether the driver had just changed gears, was missing, while others tried to interpret the message as if it had come up with no symptoms at all. The authors believe that these messages will be understood much better in real situations. In other words, a driver having just shifted hard from drive to reverse and seeing the message "SHIFT SLOWER" will correctly interpret the message, whereas drivers without such context are confused.

"Shift slower, trans damage. I don't understand how shifting slower is going to alleviate any damage to the trans. If the synchronizers are damaged, and I've been shifting at too high a speed and too fast, that may be a problem. But basically, if the

damage is there, the damage is there. I'm not worried about clutches. It's just a box of gears that slide back and forth. How much faith do I have in this alerting system? Based on what I think I know about transmissions, that is an oxymoronic message. If I've been shifting badly, it might not like it. Without synchronizing the clutch."

SAFETY SYSTEM 12, FAULT SERVICE

This message was not quantitatively measured because a large number of the responses did not reveal how drivers understood the message. The majority of subjects read the message with a pause between the first and second lines (i.e. "safety system 12... fault service"), implying that fault was grouped with service, not the first line. Although most subjects figured out the meaning after reading it a second time, some did not:

"Safety system 12, fault service. I have no idea what that means. Fault service. I guess I'd ignore messages like this and tell the company their messages don't make sense. I'm not sure what safety system 12 is. I don't know what the problem is."

The problem with interpreting answers to this message was that subjects expressed uncertainty about both the phrasing of the message and the meaning of what "safety system 12" referred to, and this uncertainty was difficult to disambiguate.

As one subject put it:

"Safety system 12, fault service. Well...if that means the safety system is at fault and I should service it, they should put a period after the word fault."

Since the focus of the study was on understandability of the messages rather than the accompanying symbols, rigorous analysis of symbol understanding was not undertaken. However, it is worth noting that in the experimenter's experience, the SRS abbreviation (used with "Safety system 12, fault service," and others) was generally not understood by drivers.

What did people do when they did not understand the message?

Although the raw numbers differ because more people understood the messages than did not, a chi-square test reveals that understanding is related to driver response in consistent ways ($p<.0001$). (See Table 16.) Drivers who did not understand the message were more likely to (1) read the driver's manual, (2) do nothing, or (3) get for help. Most notably, drivers who understood a message were more likely to (1) try to fix the problem themselves, (2) diagnose the problem themselves, or (3) just change the way they are driving at the moment. In other words, drivers who understood the message tended to take the appropriate action for the problem (e.g., close the filler door, or drive more carefully) whereas drivers who did not understand it were more likely to look in the manual, ask someone, or simply do nothing.

Table 16. Action-understandability combinations.

Action	Not Understand	Understand	Total
Change driving	3	81	84
Do nothing	15	19	34
Diagnose car	2	16	18
Fix by self	13	82	95
Get help	23	51	74
Missing data	4	7	11
Read manual	49	23	72
Stop and wait	2	4	6
Total	111	283	394

What effect does understanding have on time of response?

The effects of understanding on time of response were also significant. Overall, those who understood the message were more likely to act on it immediately, while those who did not understand tended to put it off ($p<.03$). (See Table 17.)

Table 17. When responses occurred vs. action.

When Responses Occurred	Not Understand	Understand	Total
Immediately	39	147	186
Soon	18	26	44
After trip	32	76	108
Eventually	3	7	10
Never	15	19	34
Missing data	4	8	12
Total	111	283	394

A more detailed look at drivers' behavior reveals that this effect varies by message type. One class of messages that some drivers had trouble with were the messages dealing with traction. These messages, such as "wheel spin," require an immediate response, but if the driver does not understand it, he or she may not understand the urgency. Thus, the driver may check the manual or ask someone about it, but not necessarily immediately.

The overall effect was reversed in the case of "rear backrest unlocked." (See Table 18.) Here, drivers who did not fully understand the message decided to act immediately (e.g., either by looking at the manual or experimenting with various parts of the interior of the car). Those who knew the problem was limited to the back seat tended to wait until later (e.g., their next normal stop) to fix it, since they were alone in the car.

Table 18. When drivers would respond to rear backrest unlocked.

When responses occurred	Not understand	Understand	Total
Immediately	7	1	8
Soon	2	2	4
After trip	3	12	15
Eventually	0	0	0
Never	2	0	2
Missing data	0	1	1
Total	14	16	30

Questionnaire Data

The questionnaires attempted to assess the factors that influenced the perceived urgency of warnings. Thus, questionnaires focused on the problem component of the messages and not the directive component. Drivers evaluated the drivability, risk of accident, risk of further damage, and fixability associated with each problem.

What was the perceived drivability for each problem?

The drivability questionnaire asked subjects to indicate if the vehicle could be driven, not if they would drive it. Younger drivers were more likely to perceive the problems as "normal" and less likely to perceive them as "not drivable" than older drivers. (See Table 19.) There was a slight tendency for women to respond "don't know" more often than men.

Table 19. Age differences in perceived drivability.

Drivability Answers	Young	Older	Total
Normal	152	70	222
Somewhat drivable	173	183	356
Not drivable	92	145	237
Data missing	3	2	5
Don't know	130	150	280
Total	550	550	1100

Table 20 shows the responses for warnings where it made sense to ask about drivability. Driver responses were generally in the appropriate direction, but not necessarily completely accurate. For example, responses to "fan fault" were probably confounded by whether the drivers interpreted the message as referring to the engine fan (more serious) or a compartment fan (less serious).

Table 20. Extent to which warning indicates vehicle is drivable.

Problem Name	Drivability Answers					
	Normal	Somewhat drivable	Not drivable	Data missing	Don't know	Total
a/c switched off, engine...	11	28	6	0	5	50
air bag fault	32	13	0	0	5	50
airdistr fault	16	12	0	0	22	50
brake failure	0	9	38	1	2	50
emission system C	22	10	1	0	17	50
engine fault B	1	12	6	1	30	50
engine temp high	1	25	22	0	2	50
fan fault	13	22	8	0	7	50
oil press loss	0	17	30	0	3	50
road grip exceeded	8	24	1	0	17	50
safety system 12 fault	9	8	3	1	29	50
skid control disabled	15	26	2	0	7	50
throttle fault	4	27	4	0	15	50
trans damage	0	14	26	0	10	50
trans fault	0	13	10	0	27	50
trans high temp	0	35	15	0	0	50
wheel spin	9	21	4	0	16	50
Total	141	316	176	3	214	850

What was the perceived risk of accident for each problem?

In determining the risk of accident associated with each problem, subjects were told to assume they continued driving and ignored the warning. While the term "crash" would have been more technically correct than "accident," "accident" was used because it is the term ordinary drivers used. Men were more likely than women to rate a problem as causing "no risk" of accident (143 versus 107), while women were more likely to rate a problem as causing "high risk" (86 versus 68). Women expressed more uncertainty about risk of accident than men did (84 "don't know" answers compared to 54 for males). There were no apparent differences due to age.

Table 21 shows the perceived crash risk for each message. Brake failure was clearly perceived as a high risk item. However, "road grip exceeded," an equally critical message, was perceived as high risk by only 22 percent of the drivers. Similarly, the 24 percent rating "wheel spin" as high risk is quite low.

Table 21. Perceived accident risk associated with each problem.

Problem Name	Perceived Accident Risk					
	None	Some	High	Data missing	Don't know	Total
a/c switched off, engine...	31	10	3	1	5	50
air bag fault	20	24	0	0	6	50
airdistr fault	24	5	0	0	21	50
brake failure	0	2	47	1	0	50
emission system C	40	0	1	1	8	50
engine fault B	9	19	6	0	16	50
engine temp high	18	25	7	0	0	50
fan fault	36	12	1	0	1	50
oil press loss	17	23	9	0	1	50
road grip exceeded	3	24	11	1	11	50
safety system 21 fault	9	7	6	0	28	50
skid control disabled	3	35	9	1	2	50
throttle fault	8	20	12	0	10	50
trans damage	10	20	16	0	4	50
trans fault	5	21	9	1	14	50
trans high temp	15	29	5	0	1	50
wheel spin	2	26	12	0	10	50
Total	250	302	154	6	138	850

What was the perceived risk of further damage for each problem?

Subjects were asked "What is the risk of further damage to the car if the problem goes uncorrected" and "How much further damage would be caused, if any?" Men and younger subjects tended to rate the risk of damage as being slightly lower.

Table 22 shows the ratings of risk of further damage by message. While subjects appropriately realized that oil pressure loss could cause severe damage (84 percent of those responding), an even higher figure is desired. For many of the warnings, it is uncertain if the damage expected agrees with the designers' intent.

Table 22. Risk of further damage.

Message Name	Perceived Risk of Further Damage					
	None	Some	High	Data missing	Don't know	Total
a/c switched off, engine...	12	20	14	0	4	50
air bag fault	33	8	0	0	9	50
airdistr fault	11	12	2	0	25	50
brake failure	5	14	30	1	0	50
bulb failure	44	6	0	0	0	50
emission system C	16	14	1	1	18	50
engine fault B	0	13	16	0	21	50
engine temp high	1	20	29	0	0	50
fan fault	6	24	13	0	7	50
oil press loss	0	7	42	1	0	50
safety system 12 fault	7	14	1	0	28	50
throttle fault	8	18	7	0	17	50
trans damage	0	8	42	0	0	50
trans fault	1	13	33	0	3	50
trans high temp	0	15	35	0	0	50
Total	144	206	265	3	132	750

What was the perceived cost of further damage?

Table 23 lists subjects' beliefs as to the expected cost of further damage if the warning is not heeded. Women tended to have slightly lower estimates than men. Notice that for five of the warnings, the "don't know" category is in excess of 25 percent. For two of the warnings, it is in excess of 40 percent. This reinforces the notion that many drivers did not understand some warnings.

Table 23. Cost of further damage suggested by each warning.

Problem Name	Perceived Cost of Further Damage						
	Small	Medium	High	Extreme	Data Missing	Don't Know	Total
a/c switched off, engine...	10	23	7	4	3	3	50
air bag fault	28	10	2	2	0	8	50
airdistr fault	13	13	0	1	6	17	50
brake failure	5	30	7	7	1	0	50
bulb failure	47	0	0	0	0	3	50
emission system C	13	18	2	0	4	13	50
engine fault B	2	8	12	9	2	17	50
engine temp high	3	7	26	13	0	1	50
fan fault	15	18	7	2	3	5	50
oil press loss	1	8	25	15	1	0	50
safety system 12 fault	10	12	2	0	5	21	50
throttle fault	9	12	5	2	2	20	50
trans damage	0	6	29	13	0	2	50
trans fault	0	9	33	6	0	2	50
trans high temp	1	9	31	8	0	1	50
Total	157	183	188	82	27	113	750

What was the perceived fixability for each problem?

This question addresses if subjects would be able to fix the problem indicated by each warning. The hypothesis was that if subjects could make repairs, they understood what the warning meant. It was uncertain if messages associated with problems that drivers could take care of would be viewed as more or less serious. Of those responding, less than 15 percent could "definitely" or "probably" personally take care of the problem indicated by a warning. Men were more likely than women to think that they could definitely fix the problem personally (7 percent of their responses versus 2 percent of the women's). Younger subjects tended to be more confident than older subjects, but this effect was smaller.

Table 24 shows the perceived fixability of items identified by each warning. Basically, subjects were able to replace bulbs and some could take care of oil and engine temperature problems. Everything else was beyond them.

Table 24. Perceived fixability associated with each warning (where something could be fixed).

Problem Name	Perceived Probability of Fixing Problem						
	Definitely	Probably	Don't Know	Probably Not	Definitely Not	Data Missing	Total
a/c switched off, engine...	2	7	14	13	13	1	50
air bag fault	0	0	5	14	30	1	50
airdistr fault	0	6	14	12	17	1	50
brake failure	1	5	3	5	35	1	50
bulb failure	22	18	4	3	2	1	50
emission system C	1	2	10	10	25	2	50
engine fault B	0	1	14	7	27	1	50
engine temp high	2	9	19	5	13	2	50
fan fault	1	10	9	15	14	1	50
oil press loss	3	7	9	16	14	1	50
safety system 12 fault	0	2	19	5	23	1	50
throttle fault	1	2	12	12	22	1	50
trans damage	0	1	0	7	40	2	50
trans fault	0	1	14	8	26	1	50
trans high temp	0	3	7	17	22	1	50
Total	33	74	153	149	323	18	750

Action Phrases

How urgent were the action phrases thought to be?

The 21 action phrases ranked by subjects included most of those in the message set plus others identified by the authors to be alternatives with similar meanings. For example, "service required" and "service ASAP" appear in the message test set, but "service immediately," "service at once," and "service promptly" were added for comparison. The results, arranged by mean rank, are summarized in Table 25. Notice that the word "service" by itself had the second lowest priority, while "stop safely ASAP" had the highest priority, followed by "slow down." Interestingly, "service ASAP" was in the middle of the priority rankings.

Table 25. Ranked perceived urgency of the action phrases.

Action phrase	Mean Rank	Rank by Mean	S.D.	Rank by S.D.	Min	Max
stop safely ASAP	3.00	1	3.21	11	1	13
slow down	4.32	2	4.55	18	1	21
service immediately	4.64	3	2.49	3	1	12
service urgent	5.58	4	2.53	5	1	12
service at once	5.64	5	2.52	4	1	13
service now	6.18	6	2.49	2	2	14
service imperative	6.48	7	3.43	13	1	21
service pronto	9.38	8	3.08	10	2	16
see manual	9.59	9	6.22	21	1	21
service ASAP	9.80	10	4.13	17	2	20
service promptly	10.21	11	3.41	12	2	21
call serviceshop	12.27	12	5.05	20	2	20
service necessary	13.52	13	3.69	15	6	21
service required	13.78	14	3.48	14	4	20
service needed	14.76	15	2.73	8	9	19
service shortly	15.34	16	2.81	9	9	21
service soon	15.43	17	2.60	6	10	20
contact dealer	15.74	18	4.73	19	1	21
fix next service	16.12	19	4.02	16	1	21
service	17.98	20	2.65	7	6	21
service eventually	19.56	21	1.59	1	14	21

How variable were driver interpretations of the action phrases?

Although the mean ranks are well distributed across the range of possibilities (few ties or near ties), one must also consider how consistently terms are ranked between individuals. The desire is that all drivers have a common understanding of the priority of a warning. For example, "fix next service," one of the test set warning messages, has a relatively high standard deviation (4.02), perhaps due to some subjects interpreting it to mean "fix it at the next service station" rather than the more common "fix it next time the car is in a service shop" (both interpretations occurred in the simulator part of the experiment). The phrases "service" and "fix next service" in Table 25 both have similar mean ranks, but "service" has a much smaller standard deviation (2.65 versus 4.02), making it a better choice. Table 26 shows the frequencies for the number of times each action phrase received a particular rank. To assist the reader, all cell entries in excess of 5 (10 percent of the sample) are shown in bold.

Table 26. Rank frequencies for each action phrase.

Abbreviated action phrase	Occurrences of Rank																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	2	21
stop ASAP	**30**	5		2	3	1	2	3	1	1	1		1								
slow down	**8**	**20**	5	3	2	1	2	3	1	1		1			1					1	1
s. immedtly.	3	**8**	**7**	**10**	5	**6**	4	5			1	1									
s. urgent	2	3	**7**	5	**7**	**11**	4	5	2	2	1	1									
s. at once	1	1	**7**	**10**	**8**	**8**	**7**	2	1	2	1	1	1								
s. now		3	4	5	**10**	**6**	**7**	**9**	2	1	2			1							
s. imperative	2	2	5	5	**6**	**7**	**7**	4	**6**	3		1	1								1
s. pronto		1	2		3	1	5	**8**	**7**	4	4	5	**8**	1		1					
see manual	2	3	**8**	2	1	2	5		3	4		2	2	3	1	3	1	1	1	3	2
s. ASAP		1	1	5	2	3	1	2	**8**	**7**	**6**	5	2		1	3		1	1	1	
s. promptly		1		1	2	1	3	4	5	**6**	**8**	4	4	2	1		1				1
call s. shop		2	3	1			1	2	5	3	5	4	3	2	2	2	4	**6**	2	2	
s. necessary						2		2	4	**6**	1	5	1	**9**	3	**8**	1	3	3	1	1
s. required				1	1		1		1	1	**9**	4	**6**	2	**7**	2	**10**	2	2	1	
s. needed									2	2	2	4	**6**	**7**	**8**	4	4	7	4		
s. shortly									1		2	6	5	**6**	**8**	6	3	4	5	3	1
s. soon										1	3	2	**6**	**7**	**7**	5	5	**7**	3	3	
contact dlr.	1		1						1	5	1	2	3	4	3	2	**7**	3	2	4	**10**
fix next s.	1						1	1		1	3	1	1	3	5	4	4	**10**	**6**	5	3
service						1								2	3	7	6	2	**14**	**8**	**6**
s. eventually														1		2	3	4	**7**	**17**	**16**

Although ambiguity and differing interpretations of the text are undoubtedly a factor in the standard deviation, there are probably other factors. Since subjects were instructed to put the action phrases in order according to how soon they would follow them, personal factors such as monetary resources likely factored in. Also, the relationship between urgency and time of response may not be as well correlated at low urgency levels.

In some cases a high standard deviation might be acceptable. For example, note than in Table 25, the highest standard deviation (6.22) is associated with the message "see manual." The high standard deviation is due to a systematic difference in responses rather than a few outliers. This matches the observations made in the simulator; some people consider the manual very important, while others practically ignore it, and many people are in-between. If it is not important that the driver take action right away, this action phrase might be acceptable. On the other hand, it is recommended that "see manual" not be used in urgent situations without a qualifier such as "immediately."

How did subjects categorize the action phrases by urgency?

Table 27 summarizes how many subjects put each action phrase into each urgency category. Aside from one subject whose data was lost, the missing data in this table was due to (1) subjects putting a message into two or more categories, or (2) subjects being unable to decide on a category. Notice, that across messages, there are significant individual differences in terms of how immediate each message is viewed. For example, "service necessary" would not be a highly desired action phrase because subjects thought it could be in any one of three time periods: soon,

after trip, or eventually. Interestingly, most subjects categorized "service soon" to mean after the trip, not "soon."

Table 27. Subject categorization of action phrases (sorted by immediacy).

Action phrase	Immediately	Soon	After trip	Eventually	Never	Total
stop safely ASAP	41	8	0	0	0	49
slow down	41	5	1	0	2	49
service at once	27	18	4	0	0	49
service immediately	25	19	5	0	0	49
service urgent	24	21	4	0	0	49
service now	24	19	6	0	0	49
service imperative	20	23	4	1	1	49
see manual	18	9	14	8	0	49
service pronto	12	26	10	1	0	49
service ASAP	9	23	14	3	0	49
call serviceshop	8	12	19	10	0	49
service promptly	7	17	19	1	0	44
service necessary	5	13	17	14	0	49
service	3	1	14	28	2	48
service required	2	10	22	15	0	49
contact dealer	2	6	22	16	1	47
service needed	1	11	21	15	0	48
service shortly	0	9	25	15	0	49
service soon	0	9	23	17	0	49
fix next service	1	9	6	33	0	49
service eventually	0	0	4	45	0	49

Can responses be predicted from questionnaire and urgency data?

Since drivers behave in a rational manner, how urgent drivers considered a warning to be (how soon they would respond to it) should be predictable. To examine this hypothesis, all of the independent and dependent measures of interest were translated onto a linear scale. (See Table 28.) A stepwise linear regression model was then developed using the "when" category as the dependent variable, and the questionnaire data plus the action phrase ranks as independent variables. If any independent variables were "don't know" (except for fixability), they were excluded from the model. Although other statistical approaches may be more appropriate (e.g., all of the data are ordinal, not ratio scale values), this approach nevertheless offers a reasonable first cut approximation. The model shows that the variables of risk of further damage and cost of further damage did not significantly improve predictions. This may be because these factors did not vary in the message set examined. The other four variables (drivability, risk of an accident, action phrase ranking, and fixability) were very significant.

Table 28. Terms in regression model for urgency.

Variable	Type	Description	Coding
When Category	dependent	how soon the driver would act upon the message	4=immediately, 3=soon, 2=after trip, 1=eventually, 0=never
Drivability	independent	if the car can be driven after the warning appears	3=not drivable, 2=somewhat drivable, 1=normal
Risk of Accident	independent	risk of a crash if the problem described in the warning is uncorrected	3=high, 2=some, 1=none
Risk of Further Damage	independent	physical damage to the vehicle if the warning is not heeded	3=high, 2=some, 1=none
Fixability	independent	if the driver can fix the problem without assistance	1=definitely, 2=probably, 3=don't know, 4=probably not, 5=definitely not
Cost	independent	cost of further damage	4=extreme, 3=high, 2=medium, 1=small
Action Phrase Rank	independent	ranked value of phrase in message ("service soon")	range of 1-21, 1=most urgent

According to that analysis, the urgency is predicted as follows:

When category = 2.701 + 0.453 (drivability) + 0.200 (risk of accident)
-0.044 (action phrase rank) - 0.103 (fixability)

The signs of the coefficients all seem to make sense. More immediate attention was given to (1) messages with more urgent wording, (2) those indicating the vehicle was less drivable, (3) those indicating the vehicle was more likely to have an accident, or (4) messages for problems drivers could not fix. In assessing the relative impact of these factors on driver responses, readers are cautioned to consider the scale ranges of each factor. For example, the coefficient for action phrase ranking is only -0.044. However, the coding range (1-21) is 5 to 7 times that for other independent variables. Even when that is taken into account, drivability is still the most important factor.

As an example, if a warning indicated the vehicle was drivable (=1), presented no additional crash risk (=1), definitely could not be repaired by the subject (=5) and used the term "service necessary" (=13), the "when" score would be 2.27, indicating drivers would likely to take action somewhere between soon (=3) and after the trip (=2). Changing the message wording to "stop safely ASAP" (=1) and the drivability to 3 (say for some critical engine component) would raise the score to 3.7, indicating an almost immediate response.

The regression model explains almost 40 percent of the variance associated with how soon people would respond to a warning. Given the nonoptimal statistical method employed and the degree to which many messages were not understood, this is a reasonable first approximation. It is likely that additional variance could have been explained had individual differences been examined in greater detail. However, exploration of such was beyond the scope of this experiment.

RECOMMENDATIONS FOR MESSAGES

Any simulation study risks detachment from the real world. While the experience of driving was simulated fairly closely in this study, a few important aspects of real situations were not involved in the experiment.

First, the warning messages were unaccompanied by any "symptoms" from the car. No unusual noises, smells, or handling characteristics were simulated as context for the messages. The authors believe that such context can be an important aid to understanding the meaning of warnings and acting with appropriate urgency. However, in this type of simulation, providing those other cues would have been costly and time-consuming, probably doubling the cost of the project. The cost-effectiveness of such additional cues is difficult to justify.

Second, subjects were not given a lot of time to decide on responses. The authors believe that drivers in real situations would sometimes take several minutes or more to think about it when a message appeared. Evidence for this is that some subjects changed their minds in the middle of saying what they would do. Additionally, some subjects said that in the real situation they would take more time to think before deciding. On rare occasions a subject simply could not decide what to do in the time allotted. However, in no case was a subject rushed to make a decision.

Both of the above limitations on the study would seem to indicate that these results are conservative; that is, that messages are not harder to understand than portrayed, but in fact could be easier in the context of a real situation.

In recommending messages, the authors considered both how well current messages functioned (in terms of the understandability and the actions desired) and where there were opportunities for improvements. Evaluation criteria were based on the data collected in the experiment and the research literature (Table 29). In some cases, changes to a particular message may have no effect on its understandability (e.g., listing the problem first and the solution second), but maintaining consistency might help improve the understanding of other messages in the set. *("OK, I do not know what the message means yet, but I know the first line always tells me what is wrong and the second says what to do. Give me a minute...")*

Table 29. Evaluation criteria for messages.

Criteria	Primary Question	Explanation
1. Understandability	Do drivers understand the message (as indicated by the understandability data and/or their comments)?	Do drivers say they do not understand a particular word or abbreviation? When reading a message aloud, do people pause at the wrong place (misparse it) or have trouble pronouncing a word? Can the message be clarified by adding or removing punctuation, spacing, or line breaks?
2. Desired response	Do drivers carry out the wrong action or actions at the wrong time?	This includes turning something back on when it has been automatically shut off, seeking service too late or too soon, or looking in the manual when not necessary. Ideally, if messages are well designed, drivers should never have to look in a manual to determine what a message means.
3. Error feedback	Does the message tell the driver what is wrong?	This is especially challenging for systems unfamiliar to drivers.
4. Positive guidance	Does the message tell the driver what to do?	In some cases, due to lack of space, it may not be possible to report both the error and the guidance. What to present in that situation is context-dependent.
5. Specificity	Could the driver interpret a message in more than one way?	For example, a fan fault message could refer either to the engine fan or a fan for the climate control system. In addition, there may be situations where messages report what is wrong (e.g., it is open) or what to do (e.g., open it) (the command-error problem).
6. Consistent format	Does the first line say what is wrong and the second line what to do? Is the same message phrasing always used?	(1) In some cases the reverse order did not flow as well. What is most critical is that all messages be in the same order. (2) In terms of phrasing, do not use "engine temp high" in one place and "high engine temp" in another.
7. Continuation	Is a space provided for continuation lines?	If the problem description exceeds one line, the first character of the second line should be a space so the user knows it is a continuation and not an action. This is an exception to the consistent format guideline
8. Temporal order	Does the first line say what to do first?	If there are multiple driver actions, they should be listed in the order the actions should be completed.
9. Common English	Are the terms in common American English?	Terms such as "boot" and "bonnet" should not be used. "Turn signal" is preferred to "turn indicator" and "open" to "ajar."
10. Minimum verbiage	Are the fewest characters used?	Time spent reading messages is time not spent looking at the road, so short messages are desired. However, short messages should not be provided at the cost of understandability.
11. Aesthetics	Does the message make the product look cheap?	This can results from the excessive use of contractions, spelling errors, or abbreviations (e.g., hi vs. high, lo vs. low). This is an important consideration for Volvo products in the U.S. where they are moderately expensive.

Tables 30 and 31 summarize driver responses to the messages evaluated along with recommended alternatives and comments. To facilitate implementation, they are shown upper case.

Table 30. Recommendations for messages.

Message	Understanding of message	Response Immediacy	Possible Alternative
AIR BAG FAULT A SEE MANUAL	very good	good	
STOP SAFELY ASAP AIR BAG FAULT	very good	high variance - need for air bags varies.	AIR BAG FAULT STOP SAFELY ASAP
AIR BAG FAULT CALL SERVICESHOP	very good	good	AIR BAG FAULT CALL FOR SERVICE
AIR BAG FAULT CALL SERVICESHOP (2)	very good	high variance	AIR BAG FAULT CALL FOR SERVICE
SAFETY SYSTEM 12 FAULT SERVICE	good	unclear if as desired	SAFETY SYSTEM 12 FAULT - SERVICE
DRIVE SLOWLY ENGINE FAULT A	very good	unclear if as desired	ENGINE FAULT A DRIVE SLOWLY
TRANS FAULT A SERVICE ASAP	very good	unclear if as desired	
STOP SAFELY ASAP OIL PRESS LOSS	very good	good	OIL PRESS LOSS STOP SAFELY ASAP
STOP ENGINE CHECK OIL LEVEL	very good	good - assumed adding oil & continuing is OK	
SERVICE REQUIRED EMISSION SYST C	very good	unclear if as desired	EMISSION SYST C SERVICE REQUIRED
SLOW DOWN TRANS HIGH TEMP	very good	high variance	HIGH TRANS TEMP SLOW DOWN
STOP SAFELY ASAP ENGINE TEMP HIGH	very good	good	HIGH ENGINE TEMP STOP SAFELY ASAP
ENGINE TEMP HIGH LET ENGINE COOL	very good	good	HIGH ENGINE TEMP LET ENGINE COOL
THROTTLE FAULT SERVICE ASAP	system not well understood		ACCELRATOR FAULT SERVICE ASAP
ENGINE FAULT D FIX NEXT SERVICE	very good		
STOP SAFELY ASAP BRAKE FAILURE	very good	good	BRAKE FAILURE STOP SAFELY ASAP
BRAKE FAILURE CALL SERVICESHOP	very good	good	BRAKE FAILURE CALL FOR SERVICE
AIRDISTR FAULT SERVICE REQUIRED	system not well understood	unknown if appropriate	HEAT AIRFLOW FAULT - SERVICE
A/C SWITCHED OFF ENGINE TEMP HIGH	misunderstood by >=25%	poor	A/C OFF DUE TO HIGH ENGINE TEMP
REAR LEFT DOOR AJAR	very good	good	REAR LEFT DOOR IS OPEN
FAN FAULT, SEE OWNER MANUAL	system not well understood	high variance	VENT FAN FAULT SEE MANUAL

BULB FAILURE, TURN INDICATOR	very good	good	BULB FAILURE TURN SIGNAL
FILLER DOOR AJAR	system not well understood	high variance	GAS TANK DOOR IS OPEN
REAR BACKREST UNLOCKED	system not well understood	high variance	BACK SEAT IS UNLOCKED
WHEEL SPIN	misunderstood by >=25%	high variance	ALMOST SKIDDING SLOW DOWN
SHIFT SLOWER TRANS DAMAGE	OK (would do better in context)	good	MAY DAMAGE TRANS SHIFT SLOWER
DO NOT SHIFT AT HIGH REV	OK (would do better in context)	good	DO NOT SHIFT AT HIGH REV
ROAD GRIP EXCEEDED	misunderstood by >=25%	high variance	SKIDDING SLOW DOWN
SKID CONTROL TEMP DISABLED	system not well understood	high variance	SKID CONTROL OFF SLOW DOWN

Table 31. Rationale for changing messages and comments

Original message	Rationale for Change	Other Comments
AIR BAG FAULT A SEE MANUAL	Specificity -explain FAULT A	Do not use SRS (Supplemental Restraint System). The evidence suggests SRS will be poorly understood (Common English guideline).
STOP SAFELY ASAP AIR BAG FAULT	Consistent format	Could lead some to believe the bag is about to explode. Is this the case?
AIR BAG FAULT CALL SERVICESHOP	Common English	Do not use SRS as noted above.
AIR BAG FAULT CALL SERVICESHOP (2)	Common English	Do not use SRS as noted above.
SAFETY SYSTEM 12 FAULT SERVICE	Consistent format, Continuation, Specificity -explain SYSTEM 12	
DRIVE SLOWLY ENGINE FAULT A	Consistent format, Specificity - explain FAULT A	
TRANS FAULT A SERVICE ASAP	Specificity - explain FAULT A	
STOP SAFELY ASAP OIL PRESS LOSS	Consistent format	
STOP ENGINE CHECK OIL LEVEL	Specificity - Is oil low? dirty?	
SERVICE REQUIRED EMISSION SYST C	Consistent format Specificity - explain SYST C	
SLOW DOWN TRANS HIGH TEMP	Consistent format	
STOP SAFELY ASAP ENGINE TEMP HIGH	Consistent format	

ENGINE TEMP HIGH LET ENGINE COOL	Consistent format	
THROTTLE FAULT SERVICE ASAP	Understanding (to fit accelerator is misspelled)	Common English guideline (gas pedal) may only suggest the pedal itself, not the linkage.
ENGINE FAULT D FIX NEXT SERVICE	Specificity - explain FAULT D	
STOP SAFELY ASAP BRAKE FAILURE	Consistent format	May imply no brakes. Is this the case?
BRAKE FAILURE CALL SERVICESHOP	Consistent format, Common English	Should it be failure or failing?
AIRDISTR FAULT SERVICE REQUIRED	Understanding	
A/C SWITCHED OFF, ENGINE TEMP HIGH	Understanding	
REAR LEFT DOOR AJAR	Common English	
FAN FAULT, SEE OWNER MANUAL	Understanding - engine or climate fan	
BULB FAILURE, TURN INDICATOR	Common English	EXT. BULB FAILURE, TURN SIGNAL could be clearer, but EXT. may not be understood.
FILLER DOOR AJAR	Understanding	
REAR BACKREST UNLOCKED	Understanding	This message still needs work as it lacks a references to unsecured seat belts.
WHEEL SPIN	Understanding	
SHIFT SLOWER TRANS DAMAGE	Consistent format, Specificity	The existing message suggests the trans is damaged. In the U.S., the action is called rocking.
DO NOT SHIFT AT HIGH REV	Consistent format	
ROAD GRIP EXCEEDED	Understanding, Positive guidance	
SKID CONTROL TEMP DISABLED	Understanding of skid control. Is temp=temperature? Consistent format	The new message does not indicate the brake temperature problem, a difficult connection for drivers. Even with the revised warning, drivers may just turn the skid control back on.

Understanding was rated "very good" for messages that drivers had no trouble interpreting (less than 5 percent of drivers had any trouble at all). A rating of "good" implies that the message is generally understood by all drivers, but for some reason comprehension is compromised. In two cases a message's understandability was rated "OK." These messages were actually hard to understand with a minimum of context, but in the specific context of a situation in which the message would arise, the authors believe the message will be generally understood.

How soon a driver needed to respond to a warning depended upon the severity of the problem. Messages in which the subjects' responses were consistently appropriate were labeled "good" in the above table. Some messages with for which the response was highly variable might be acceptable in some cases (e.g., if a problem requires that the driver look at the manual within a few weeks, it is not necessarily a problem that some subjects consulted the manual immediately).

authors recommend that Volvo examine the response distribution tables for messages with high variation and evaluate for themselves if the patterns are acceptable.

Although it could be said that drivers' responses to messages are more important than their understanding of them, in practice it appears that poor understanding of the system mentioned in the message leads to high variability of response. Rigorous comparisons of perceived urgency with actual severity of the problem was not attempted in this study. Rather, the focus has been on what will drivers do in the hope that message designers will be able to use these results to assess existing warning messages as well as knowledgeably construct new warning messages.

This report establishes the foundation for an approach to develop and evaluate in-vehicle warning messages. It provides a simulator method for evaluating warnings and provides data on driver understanding for a real set. This report also identifies the characteristics that influence how soon drivers respond to warnings and provides an equation to predict that time period. This information should prove useful in designing safer motor vehicles for the future.

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APPENDIX A - EXAMPLE DATA ON DRIVER UNDERSTANDING

Table 32. Questions concerning driver knowledge of their vehicles.

Question	Response
What is the normal operating temperature of your car's engine?	Estimates varied from 45 to 275 degrees F. Of those responding, 44/66 did not know what normal was, and only about 5 responded correctly (180-190 degrees F).
How hot can your car engine get before it is considered to be overheated?	Estimates varied from 80 to 350 degrees F. Of those responding, 41/66 did not know what normal was, and only about 5 responded correctly (230-240 degrees F)
What is the voltage of your car's battery?	Thirty-nine of the 66 subjects said 12 volts and one subject said 6 volts (correct for his vehicle, a VW bus).
If your car had an instrument panel gauge labeled volts, what would be a representative reading when the engine is running?	Of the 66 participants, 23 gave a value in the 12-14 volt range. Some 32 drivers did not know.
If there was a gauge labeled amps, what would be a representative number when the engine is running?	Some 41 of the 66 drivers did not know. Only 4 drivers said 0.

Table 33. Driver understanding of vehicle conditions and components.

Question	Correct	Somewhat Correct	Wrong
What happens if the radiator fluid is too low?	27	0	0
What happens if the power steering fluid is too low?	20	4	3
What do the shock absorbers do?	20	3	4
What is the battery for?	18	8	1
What happens if the brake fluid is too low?	15	6	6
What happens if a fuse blows?	15	9	3
What is special about anti lock brakes?	14	7	6
What happens if the engine oil level is too low?	12	11	4
What happens if the oil pressure is too low?	12	5	10
What happens if the tire pressure is too low?	11	13	3
What happens if the wheels are not aligned?	11	15	1
What is the clutch for?	9	16	2
What happens if the anti lock brakes don't work?	8	9	10
What do fuses do?	8	7	12
What is an alternator for?	7	11	9
Why does the engine oil need changing?	7	14	6
What do the struts do?	7	15	5
What happens if the tires are very worn?	7	20	0
What does the master cylinder do?	7	8	12
What does the catalytic converter do?	6	16	8
What does wheel alignment refer to?	5	17	5
What is the accessory drive belt for?	5	2	20
What happens if the alternator does not work?	4	18	5
What does the oxygen sensor do?	2	8	17
What does transmission fluid do?	2	16	9
Mean	10.4	10.2	6.4

APPENDIX B - ADDITIONAL BIOGRAPHICAL INFORMATION

Table 34. List of subject occupations and vehicles driven.

Occupation	Year	Make	Model
(Ret) Clerk-Kellogg Eye Ctr	94	Chevy	Euro
Statistician	94	Toyota Camry	Camry
Office Asst. II	90	Geo	Prism
Librarian	89	Pontiac	Sunbird
Student Advisor	90	SAAB	9000CD Turbo
Admin. Asst.	84	Toyota	Tercel
Web Designer/ Records manager	93	Mercury	Sable
Housemaker/ mother	92	Plymouth	Voyager
(Student) Human Comp. Interaction	88	Ford	Mustang
Analyst	97	Chevy	Cavalier
Engraver	92	Mercury	Grand Mar
(Ret) Truck Driver	96	Mercury	Marquis
Real Estate Appraiser	88	Ford	Taurus
Executive	84	Pontiac	Wagon
Postal Worker & Real Estate Sales	92	Buick	Park Ave
(Student) Biomedical Eng.	91	Nissan	Sentra
Freelance editor	96	Dodge Caravan	Caravan
Teacher	89	Acura	Legend
Homemaker	87	Olds	Cutlass
Client Acquisition Specialist	91	Volvo	940GLE
(Student) Library Asst. II	89	Plymouth	Sundance
(Student) History	84	Mazda	GLC
(Student) Music	62	VW Bus	Bus
(Student) Ind & Ops Eng	84	Volvo	240DL
(Student) Biophys/ pharmacology	95	Dodge	Neon Spirit
Chiropractor	87	Olds	Cutlass

Occupation	Year	Make	Model
(Retired) PR/News Director	94	Ford	Explorer
(Ret) Marketing/ Insurance	91	Plymouth	Voyager
Medical Technologist	92	Chevy	Blazer
(Ret) Retail Shop Owner	89	Audi	100
Planning Consultant	85	GMC	Van
(Stu) Comp. Eng.	93	Chevy	Cavalier
(Ret) Office Supervisor	84	Chevy	Blazer
(Ret) Postmaster	88	Dodge	Dynasty
Homemaker	97	Honda	Civic
Assembler-Special needs products	91	Toyota	Tercel
Law Enforcement (Forensic Auditing)	95	Chevy	Lumina
Research Associate	94	Plymouth	Van
(Ret) Gen Supv. Tool line	90	GMC	Suburban
Duplicator Operator	92	Toyota	Tercel
(Ret) Admin Asst UM	92	Pontiac	Grand Am
Homemaker	84	Lincoln	Town Car
(Student) Biology	91	Ford	Escort
Res. Secretary	85	Chevy	Wagon
(Student) Computer Science	91	Nissan	SE-R
Libr. Admin.	90	Chrysler	LeBaron
(Ret) Res. Assoc.	96	Chrysler	Minivan
Comp. Scientist	92	Mazda	Protege
Engineering Tech.	92	Mercury	Grand Marquis
Nuclear Engineer	85	Toyota	Camry
Program Asst.	91	Ford	Tempo

APPENDIX C - LIGHTING CONDITIONS

Lighting measurements were obtained from one warning ("stop safely ASAP, brake failure"). Since all warnings were generated by the same hardware and software using the same font and symbols, all appearing in the same location, their luminance and illuminance characteristics should be identical. Illuminance was measured with a YFE Digital Lux Tester (YF-1065). The illuminance was measured at the location of the warning. Luminance was measured with a Spectra Pritchard Photometer (1980A-CD and OP) using a 2' luminance head.

Because of the small strokewidth of the warning text, measuring luminance was a challenge. To provide for more accurate luminance readings, a white patch adjacent to the text (but equivalent in generated luminance) was also measured. Data was also obtained for the general warning icon in the center of the display (the background of the ! icon) and on the right (the background of the ABS icon).

Legibility computations used the NBS (National Bureau of Standards) Methods, a quantitative value for legibility (Howett, 1983). When the measured height (H_m) is greater than the computed height (H_c), the character is legible. The relative legibility of a character is represented by the ratio of H_m/H_c. Data for a reasonable worst case scenario of 20/40 vision and a viewing distance of 83 cm is show in Table 35.

Table 35. NBS Calculations for a viewing distance of 83 cm and 20/40 acuity

Location	Colors	Luminance (cd/m2)		Hm	Hc	NBS	Legible?
		Character	Background	(mm)	(mm)	Hm/Hc	
text	white/black	13.86	0.18	6.0	4.10	1.46	Y
white patch	white/black	17.30	0.18	6.0	3.90	1.54	Y
! icon	black/red	0.18	3.03	6.0	5.80	1.03	Y
ABS icon	black/yellow	0.18	14.87	3.6	2.40	1.50	Y

As seen in Figure 5, legibility improves considerably when the subject's visual acuity is 20/20. In addition, improved legibility is also seen when the subject is seated closer to the display. The H_m of the actual characters is shown as a line. All variants shown are legible.

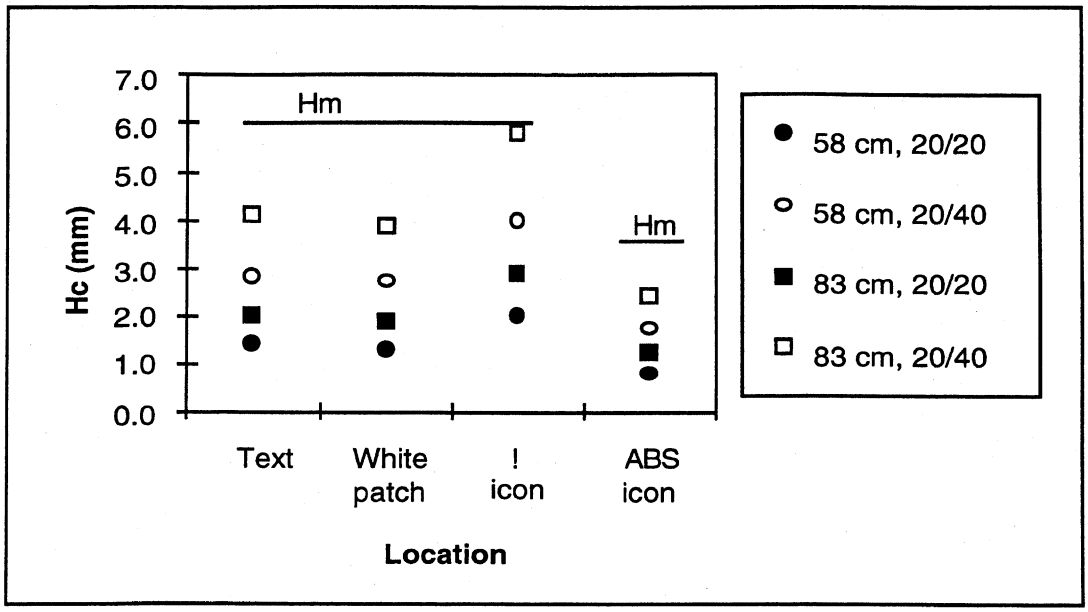


Figure 5. Legibility for different seating distances and visual acuities

APPENDIX D - ADDITIONAL EQUIPMENT DETAILS

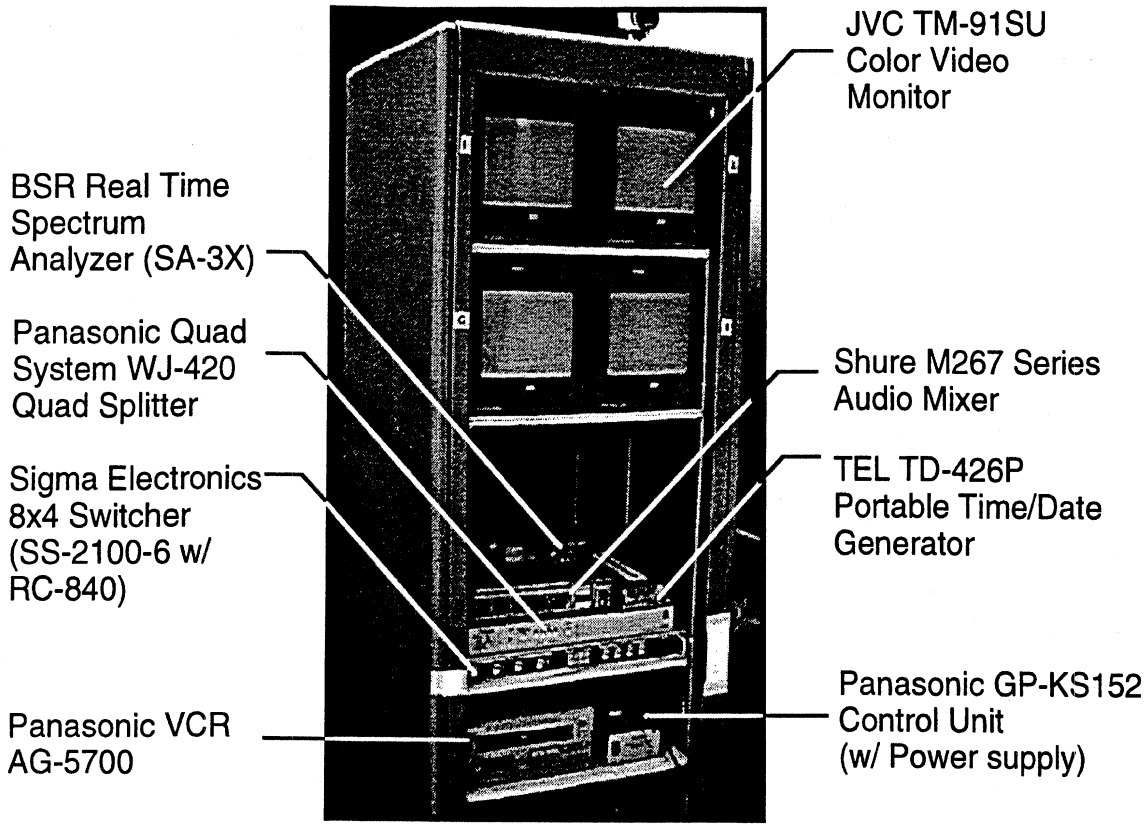


Figure 6. Video rack in driving simulator.

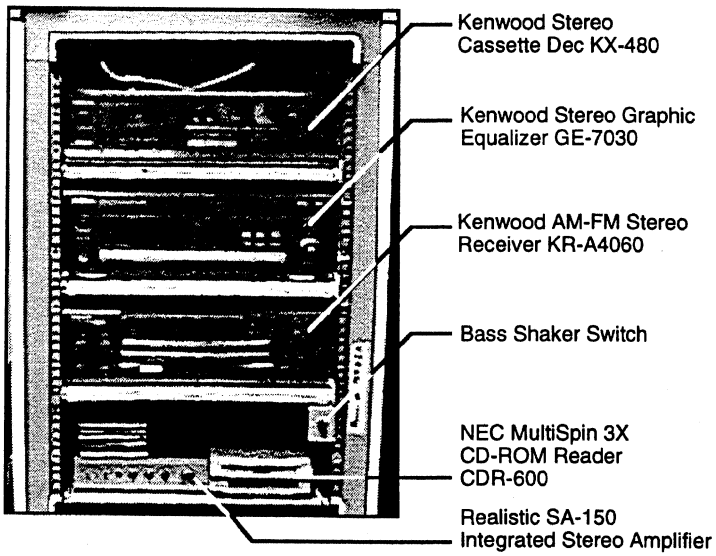


Figure 7. Audio rack in driving simulator.

APPENDIX E - INSTRUCTIONS TO SUBJECTS

Procedure for Volvo Study

Before subject arrives:

Get cash

- Set up all equipment (if first subject of the day)
  - ⇒ cameras -- focus
  - ⇒ touchscreen
  - ⇒ Duo
  - ⇒ video tape (labeled) -- start recording
  - ⇒ sound & shakers -- 3.2 sound generator!
  - ⇒ overhead projector
  - ⇒ IP projector (are gauges centered?)
  - ⇒ start simulator
- Have the following sheets ready
  - ⇒ participant consent form
  - ⇒ biographical form
  - ⇒ payment forms / support voucher forms
  - ⇒ response categories form
  - ⇒ $15 for non-UM employees
  - ⇒ drivability form
  - ⇒ accident form
  - ⇒ damage form
  - ⇒ knowledge form

Hi, are you (participant's name)**? I'm Dan. Thank you for coming today. Let's go to the conference room and get started.**

Overview

This study concerns warning messages in cars. The study will take about an hour to complete, and you will be paid $15 for your time. You will be asked to operate a driving simulator and respond to various messages and warning lights in the car.
Before starting, there are some forms for you to fill out. Afterwards, I will provide more detailed instructions.

Biographical and Consent Forms

First, please read and sign this consent form, and then turn the page and fill out the biographical form.

I want to emphasize that some people experience motion sickness while driving the simulator. If you feel uncomfortable, there will be no problem stopping the experiment. You will be paid the full amount, even if you are unable to complete the study. If you have any questions, feel free to ask them at any time.

Provide consent and biographical forms. Check that the responses are legible and complete.

Vision Test

Next, I'll be checking your vision. Do you use any corrective eyewear while you drive? If subject answers yes - **Could you please put them on?** Subject puts face up to vision tester. **Can you see in the first diamond that the top circle is complete but the other 3 are broken? In each diamond, tell me the location of the solid circle - top, left, bottom, or right.** Continue until 2 in a row are wrong. Take the last one that was correct as the visual acuity. **OK. Now we'll go down to the simulator laboratory where I'll explain the next phase.**

In the Simulator

Please step into the simulator, adjust the seat and fasten your seat belt. Here is the seat control. Subject adjusts seat belt and seat.
In a moment I'll start the simulator and you can start driving. The road is fairly straight, and you won't see any other vehicles.

I'd like you to pretend you are driving by yourself in your 1-year-old manual transmission car to meet a friend in East Lansing, 1 hour away. It's around 2 P.M. on a nice fall day, and you are driving on the expressway. You just left your home in Ann Arbor 10 minutes ago. Your car has a cell phone.

Try to stay at roughly 50 miles per hour and in your lane. Periodically a warning light and message will appear on the display in the center of the dashboard. Flash example warning message. **When this happens, I'd like you to first read the message to me. Then tell me two things:**

1) **what the message means (for example, what's wrong with the car), and**
2) **what you would do in response to it**

In your response, if you want to call someone, you can assume you have a car phone. If you want to look in the owner's manual, you can assume you have one. If your response involves stopping

immediately, I will ask you to reduce speed to about 15 mi/hr (but don't actually stop) and then look for another message on the display.

Give them a table of responses

When you are done answering, please press "Clear" on the screen to make the message disappear. You might have to press a little harder on the screen than you expect. When you see a message, tell me what the message means; then tell me what you'd do in response to it. If you would normally stop the car, please slow down to about 15 mph.

We're not measuring how fast you can react to these messages; we just want to know how easy they are to understand. We want your initial reaction.

Calibrate wheel and pedals.

As a reminder, some people may experience a bit of motion discomfort initially, but this normally subsides after a few minutes. If at any time you need to take a break or do not feel as though you can continue with the study, please tell me and I'll stop the simulator. Do not be a hero. If you are ready, hold on to the wheel and I will start the simulator.

Start simulator. Turn torque motor on. Let subject drive for one minute. Ask how they're feeling. If they're OK, let them drive for 30 seconds more and flash the first warning message.

Continue with the other 25 messages, noting responses on PowerBook.

OK, that's all of the warning messages. Please slow down. I'm going to stop the simulator now. Stop simulator. **Let's go back in the other room for a few final questions.**

Have subject fill out post-experiment questionnaires.

Have subject fill out payment form. If non-University employee, give them money. Otherwise, tell subject that amount will be added to his/her next paycheck.

Thanks again for participating. Walk subject back to third-floor elevator.

Turn voucher in to Denise.

APPENDIX F - CONSENT FORM

Consent Form

The purpose of this experiment is to (1) determine how well drivers understand messages and warnings that might be provided in cars of the future, and (2) identify characteristics that make the messages understandable. The intent is to make future cars that you might drive more "user friendly."

Your task will be to drive a simulator that will periodically show messages on the instrument panel. In response to them, you will tell the experimenter what each message means and how you would respond to each message. At the end, you will be asked questions regarding what you considered in making decisions. The experimenter will transcribe what you say, and for completeness, will videotape your responses (including audio). We may show segments of a few of these tapes to others to indicate participant responses. Names will not be released, though we release a transcript of what is said.

There are no significant risks in participating in this experiment, though sometimes people experience motion discomfort in the simulator. If that occurs, just ask the experimenter to stop.

The entire study will take about an hour to complete. You will be paid $15 for your participation. You can withdraw from the study at any time and for any reason. You will be paid regardless.

I have reviewed and understand the information presented above. My participation in this experiment is entirely voluntary.

_____ _____

Subject Signature Date

_____ _____

Subject Name (PRINTED) Witness

Investigator: Paul Green 763-3795

APPENDIX G - BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute
Message Understanding Study
Biographical form

Subject: Date: Time:

Name:_____ **Age:**_____

Sex(circle one): **Male Female**

Occupation:_____

Retired or Student: Note your former occupation or major_____

Are you a licensed driver? **Yes No**

What kind of car do you drive the most?

Year:_____ Make:_____ Model:_____

Approximate annual mileage:_____

Approximately how often do you use a computer?

Daily Weekly Monthly Less

Do you have a cell phone? **Yes No**

Have you ever driven a car that had a text-based (not just lights) warning system which could give reminders about items such as maintenance, oil-changes, broken headlights, open doors, anti-lock brake failure, etc.? **Yes No Unsure**

Do you subscribe to or read any popular auto magazines (such as *Automobile, Car & Driver,* etc.) **?** **Yes No Unsure**

Have you ever changed the oil in a car yourself (including draining the oil)? **Yes No Unsure**

Are you a native English speaker? **Yes No Unsure**

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? Y / N
which?

How drivable is the car, assuming there are no other symptoms than the warning message?

UMTRI
Message Understanding
drivability ratings form

Subject #

car won't move

ex: can drive at reduced speed, or with some restrictions

can drive as normal

Problem:	Drivability (circle one for each problem):			
1. AIR BAG FAULT	not drivable	somewhat drivable	normal	don't know
2. TRANS HIGH TEMP	not drivable	somewhat drivable	normal	don't know
3. ENGINE FAULT B	not drivable	somewhat drivable	normal	don't know
4. TRANS FAULT A	not drivable	somewhat drivable	normal	don't know
5. BRAKE FAILURE	not drivable	somewhat drivable	normal	don't know
6. ROAD GRIP EXCEEDED	not drivable	somewhat drivable	normal	don't know
7. FAN FAULT	not drivable	somewhat drivable	normal	don't know
8. EMISSION SYST C	not drivable	somewhat drivable	normal	don't know
9. OIL PRESS LOSS	not drivable	somewhat drivable	normal	don't know
10. ENGINE TEMP HIGH	not drivable	somewhat drivable	normal	don't know
11. WHEEL SPIN	not drivable	somewhat drivable	normal	don't know
12. THROTTLE FAULT	not drivable	somewhat drivable	normal	don't know
13. AIRDISTR FAULT	not drivable	somewhat drivable	normal	don't know
14. A/C SWITCHED OFF ENGINE TEMP HIGH	not drivable	somewhat drivable	normal	don't know
15. SKID CONTROL TEMP DISABLED	not drivable	somewhat drivable	normal	don't know
16. TRANS DAMAGE	not drivable	somewhat drivable	normal	don't know
17. SAFETY SYSTEM A FAULT	not drivable	somewhat drivable	normal	don't know

APPENDIX I - ACCIDENT RISK FORM

UMTRI
Message Understanding Study
accident ratings form

Subject #

Risk of accident because of this problem (if problem goes uncorrected)

Accident will probably result from this problem

Accident is possible

Accident will not result from this problem

Problem:	Risk of accident (circle one for each problem):			
1. AIR BAG FAULT	high	some	none	don't know
2. TRANS HIGH TEMP	high	some	none	don't know
3. ENGINE FAULT B	high	some	none	don't know
4. TRANS FAULT A	high	some	none	don't know
5. BRAKE FAILURE	high	some	none	don't know
6. ROAD GRIP EXCEEDED	high	some	none	don't know
7. FAN FAULT	high	some	none	don't know
8. EMISSION SYST C	high	some	none	don't know
9. OIL PRESS LOSS	high	some	none	don't know
10. ENGINE TEMP HIGH	high	some	none	don't know
11. WHEEL SPIN	high	some	none	don't know
12. THROTTLE FAULT	high	some	none	don't know
13. AIRDISTR FAULT	high	some	none	don't know
14. A/C SWITCHED OFF ENGINE TEMP HIGH	high	some	none	don't know
15. SKID CONTROL TEMP DISABLED	high	some	none	don't know
16. TRANS DAMAGE	high	some	none	don't know
17 .SAFETY SYSTEM A FAULT	high	some	none	don't know

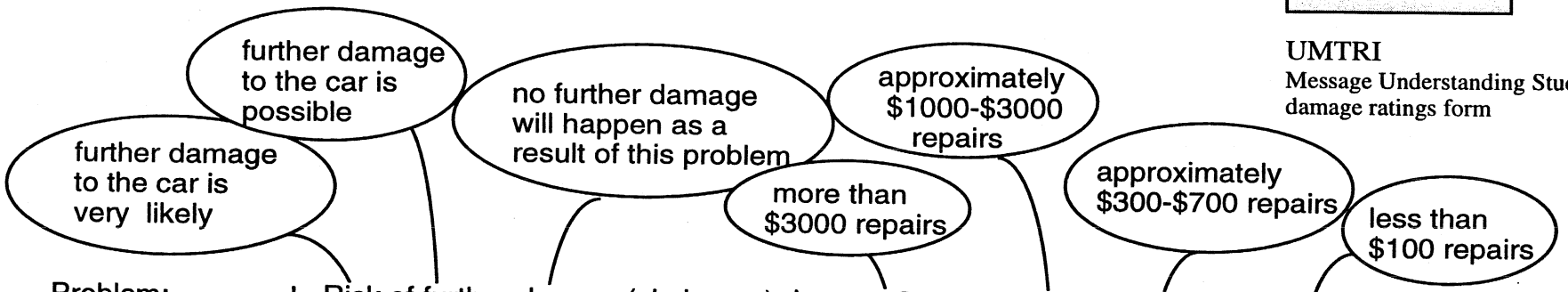
If there is an accident not because of this problem, how much worse would any injuries be?

Problem:	how much worse the injuries would be				
1. AIR BAG FAULT	much	somewhat	a bit	none	don't know
2. SAFETY SYSTEM A FAULT	much	somewhat	a bit	none	don't know

Risk of further damage if the problem is not corrected (assuming an accident does not occur)

Subject #

UMTRI
Message Understanding Study
damage ratings form



Problem:	Risk of further damage(circle one):				Cost of further damage (if any):				
1. AIR BAG FAULT	high	some	none	don't know	extreme	high	medium	small	don't know
2. TRANS HIGH TEMP	high	some	none	don't know	extreme	high	medium	small	don't know
3. ENGINE FAULT B	high	some	none	don't know	extreme	high	medium	small	don't know
4. TRANS FAULT	high	some	none	don't know	extreme	high	medium	small	don't know
5. BRAKE FAILURE	high	some	none	don't know	extreme	high	medium	small	don't know
6. BULB FAILURE TURN INDICATOR	high	some	none	don't know	extreme	high	medium	small	don't know
7. FAN FAULT	high	some	none	don't know	extreme	high	medium	small	don't know
8. EMISSION SYST C	high	some	none	don't know	extreme	high	medium	small	don't know
9. OIL PRESS LOSS	high	some	none	don't know	extreme	high	medium	small	don't know
10. ENGINE TEMP HIGH	high	some	none	don't know	extreme	high	medium	small	don't know
11. THROTTLE FAULT	high	some	none	don't know	extreme	high	medium	small	don't know
12. AIRDISTR FAULT	high	some	none	don't know	extreme	high	medium	small	don't know
13. A/C SWITCHED OFF ENGINE TEMP HIGH	high	some	none	don't know	extreme	high	medium	small	don't know
14. TRANS DAMAGE	high	some	none	don't know	extreme	high	medium	small	don't know
15. SAFETY SYSTEM A FAULT	high	some	none	don't know	extreme	high	medium	small	don't know

UMTRI
Message Understanding Study
knowledge form

Subject #

maybe/
not enough information

Problem:	Are you able to fix it?				
1. AIR BAG FAULT	definitely	probably	don't know	probably not	definitely not
2. TRANS HIGH TEMP	definitely	probably	don't know	probably not	definitely not
3. ENGINE FAULT B	definitely	probably	don't know	probably not	definitely not
4. TRANS FAULT A	definitely	probably	don't know	probably not	definitely not
5. BRAKE FAILURE	definitely	probably	don't know	probably not	definitely not
6. BULB FAILURE TURN INDICATOR	definitely	probably	don't know	probably not	definitely not
7. FAN FAULT	definitely	probably	don't know	probably not	definitely not
8. EMISSION SYST C	definitely	probably	don't know	probably not	definitely not
9. OIL PRESS LOSS	definitely	probably	don't know	probably not	definitely not
10. ENGINE TEMP HIGH	definitely	probably	don't know	probably not	definitely not
11. THROTTLE FAULT	definitely	probably	don't know	probably not	definitely not
12. AIRDISTR FAULT	definitely	probably	don't know	probably not	definitely not
13. A/C SWITCHED OFF ENGINE TEMP HIGH	definitely	probably	don't know	probably not	definitely not
14. TRANS DAMAGE	definitely	probably	don't know	probably not	definitely not
15. SAFETY SYSTEM A FAULT	definitely	probably	don't know	probably not	definitely not

APPENDIX K - PAYMENT FORM

The University of Michigan
Subject Fee Payment Form

Date: ___/___/___

University Department: UMTRI (Human Factors)

Departmental Contact Person & Telephone #: Denise Creque, 4-6506

Department Reference Number: Account No. 375136

Study Name: Factors in Warning Message Understanding and Response

TO BE COMPLETED BY VOLUNTEER:

_____
Volunteer Name

_____
Social Security #

_____
Street Address

_____
City, State, Zip

Are you a University of Michigan Employee? Yes _____ No _____

I hereby acknowledge that I have received the below stated amount as full payment for my participation in the above described project.

_____
Volunteer's Signature

TO BE COMPLETED BY DEPARTMENT:

Amount: $ _____ Given from cash receipt number (if applicable): _____

Authorized Signature: _____
Paul Green

Payment made by: _____ Date: ___/___/___

Payment amount limited to $50 or less per subject.