In-Vehicle Display Icons and Other Information Elements

Volume I: Guidelines

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IN-VEHICLE DISPLAY ICONS AND OTHER INFORMATION ELEMENTS: VOLUME I: GUIDELINES

FOREWORD

This is one of a series of reports produced as part of a contract to develop precise and detailed human factors design guidelines for in-vehicle display icons and other information elements. The contractual effort consists of three phases: analytical, empirical, and integrative.

This report is a product of the integrative phase. This handbook summarizes human engineering data, guidelines, and principles for use by designers during the development and evaluation of in-vehicle icons and other information elements.

Copies of this report can be obtained through the Research and Technology Report Center, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706; telephone: 301–577–0818; fax: 301–577–1421; or the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161; telephone: 703–487–4650; fax: 703–321–8547.

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NOTICE

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16. Abstract:
Because of the speed with which, In-Vehicle Information System (IVIS) devices are entering the automotive marketplace, many research issues associated with the design of in-vehicle visual symbols and other information elements have not been adequately addressed. The overall goal of the *"In-Vehicle Display Icons and Other Information Elements"* project has been to provide the designers of these in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. Specific objectives of this project were to:

- Design and perform experimentation to select appropriate symbols for in-vehicle use; use the resulting data to write final guidelines for in-vehicle symbols usage, encompassing both current and future symbols.
- Write preliminary, as well as empirically based, final guidelines.

The key product of this project is a set of clear, concise, and user-centered human-factors design guidelines for in-vehicle icon design. The 42 guidelines address issues such as the legibility, recognition, interpretation, and evaluation of graphical and text-based icons and symbols. These guidelines provide IVIS developers with key information regarding the use and integration of existing and new visual symbols. In addition, guidelines are provided for the design of in-vehicle auditory information.

17. Key Words	18. Distribution Statement
Human Factors, Driver Information, Design Guidelines, Icon Design, Visual Symbols, Icon Interpretation, Icon Legibility, Auditory Messages, General vs. Specific Icons, Icon Recognition, Icon Evaluation	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

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None	None	238	

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1: HOW TO USE THESE DESIGN GUIDELINES

INTRODUCTION

These guidelines are intended for use by anyone responsible for the conceptualization, development, design, testing, or evaluation of in-vehicle display icons and other information elements. During future project activities, these guidelines will be revised and expanded.

Chapters 2 through 7 contain the preliminary design guidelines produced through this effort. Chapter 2 provides general guidelines for icon design, and focuses on issues associated with the development of icons, when to use icons, and icon comprehension. Chapter 3 provides design guidelines for icon legibility, and focuses on issues associated with contrast, luminance, and the use of color. Chapter 4 provides design guidelines for icon recognition, and focuses on issues associated with the level of detail, the level of realism, and principles of perception to follow for the design of effective icons. Chapter 5 provides guidelines for icon interpretation, and focuses on the use of icons to convey system status and the effect of actions, and on identifying icons as part of a group. Chapter 6 provides guidelines for presenting auditory in-vehicle information, and focuses on the design of simple tones, earcons, auditory icons, and speech messages. Chapter 7 provides guidelines for the evaluation of in-vehicle icons, and focuses on the tests recommended by the International Organization for Standardization (ISO) (i.e., production test, appropriateness ranking test, comprehension/recognition test, and matching test). Chapter 8 includes a collection of icons for many messages. A tutorial describing in detail the process necessary for converting rank orders to scale values when evaluating icons using the appropriateness ranking test is provided in chapter 9. A design tool, useful for determining the sensory mode for presenting in-vehicle information, is provided in chapter 10.

This handbook can be used by individual designers in any number of ways. For example, it can be read, from start to finish, if one desires an overview of human factors issues, principles, data sources, and guidelines associated with the design of in-vehicle display icons. Alternatively, individual chapters can be reviewed by designers who would like to focus on specific topics, such as icon evaluation. Finally, designers may simply refer to specific guidelines, equations, terms, and references as their individual needs warrant. Thus, there is no “right” way to use this handbook—the day-to-day needs of the individual designer will dictate how and when it should be used.

THE TWO-PAGE FORMAT

In this handbook, a two-page format is used to present each design guideline. On each page, the main issue (e.g., Icon Legibility, Icon Recognition) being addressed by the guideline is indicated by centered, bold type within the header. As described in more detail below, the left-hand page presents the title of the guideline, an introduction and overview of the design guideline, the design guideline itself, the rating associated with the guideline, and a graphic, table, or figure that augments the text information. The right-hand page provides the more detailed supporting rationale for the design guideline that a designer may need to perform his or her day-to-day design tasks, as well as special design considerations, a space for designer notes, and a list of key

references. A sample guideline, with key features highlighted, is shown below in figure 1-1; a detailed description of the presentation format of the guidelines follows.

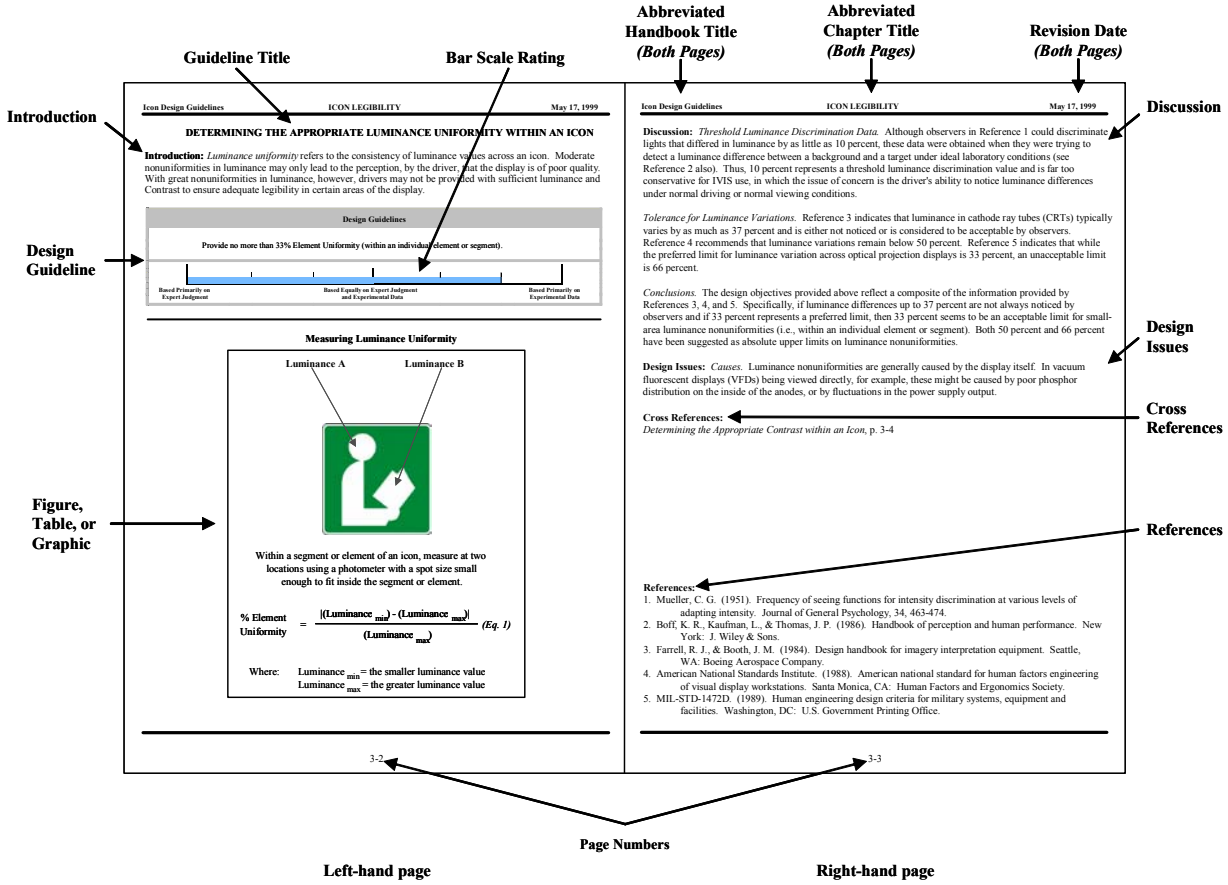


Figure 1-1. Format Used in the Preliminary Design Guidelines

THE LEFT-HAND PAGE

The guideline title is indicated by centered, bold type at the top of the left-hand page.

Introduction

This subsection briefly defines the design guideline and provides basic information about the design parameter and the guideline. For example, this subsection might be used to provide the unit of measurement (e.g., visual angle, meters, footlamberts, etc.) for the guideline, or to provide equations for the derivation of certain parameters.

Design Guideline

This subsection presents a quantitative design guideline (when possible), either as a point value, a range, or an explicit recommendation. The design guideline is always presented prominently and is enclosed in a gray box that is centered on the page.

In some cases, the design guideline is presented qualitatively in general terms (e.g., "text labels should be brief"). However, in most cases, the design guideline is presented quantitatively (e.g., "text labels should be no more than 2-3 words").

The Rating System

For some design parameters, enough empirical data exist to provide well-supported design guidelines, and the use of expert judgment is minimal. For others, empirical data have only provided the foundation for a decision about what the design guideline should be, but experience and judgment have been used to determine the final design guideline. For yet other topics, little or no empirical data were available, and the design guideline was based primarily on expert judgment.

To aid in-vehicle display designers in making design trade-offs, individual design guidelines have been rated according to the relative contribution of empirical data and expert judgment to the design guideline. Specifically, each design guideline has been rated along a continuum and falling somewhere between "Based Primarily on Expert Judgment" and "Based Primarily on Experimental Data."

- ***Based Primarily on Expert Judgment.*** Little or no empirical data were used to develop this design guideline. Expert judgment and design convention were used to develop this design guideline.

- ***Based Equally on Expert Judgment and Experimental Data.*** Equal amounts of expert judgment and experimental data were used to develop this design guideline. Research findings may have lacked consistency, requiring greater amounts of expert judgment. Or, research may have been lacking in this specific area, requiring the results of research from related content domains to be interpreted for use in this context.

- ***Based Primarily on Experimental Data.*** Based on high quality and consistent data sources that apply directly to the guideline. Empirical data from highly relevant content domains (e.g., transportation human factors, navigation system design) were primarily used to develop this design guideline; little expert judgment was required.

Figure, Table, or Graphic

A figure, table, or graphic augments the design guideline and provides "at-a-glance" information considered to be particularly important to the conceptualization and use of the design guideline. It provides a visual representation of the design guideline (or some aspect of the design guideline) that may be difficult to grasp from the design guideline itself, which is quantitative and text-based.

This figure, table, or graphic might take many forms, including: a drawing depicting a generic application of a design guideline or a particular design issue, a flowchart of measurement procedures for the design guideline, a table that summarizes the design guideline, or schematic examples of particular icons or symbols.

THE RIGHT-HAND PAGE

Discussion

This subsection briefly summarizes the rationale behind the choice of the design guideline. In particular, the discussion explains the logic, premises, assumptions, and the train-of-thought associated with development of the guideline. The discussion can take many forms, including a brief review of applicable empirical studies, references to traditional design practice, or an analysis of relevant information.

The discussion is presented primarily to help designers understand and explain or justify the design guideline to other members of the development team. Also, since these human factors design guidelines are expected to be revised as additional empirical data become available, this subsection will be useful to future developers of design guidelines. In particular, the discussion will enable future design guideline developers to determine how new human factors information can (or should) be integrated into the existing design guidelines.

For example, the design guideline for daytime symbol contrast has been developed through consideration of expected "worst case" ambient luminance, anticipated driver populations, and contrast requirements under representative laboratory conditions. If new data for the "worst case" ambient luminance are obtained (or if new assumptions are made), future guideline developers will be able to assess the role and relative importance of ambient luminance associated with the current design guideline for daytime symbol contrast and determine what (if any) changes should be made.

Design Issues

This subsection presents special design considerations associated with a particular design guideline. These special considerations might include design goals from the perspective of other disciplines (e.g., optics, packaging, displays), interactions with other design guidelines, special difficulties associated with the guideline's conceptualization or measurement, or special human performance implications associated with the design guideline.

Cross References

This subsection lists the titles and page numbers of other guidelines within the handbook that are relevant to the current guideline.

References

This subsection lists the references associated with the formulation of the design guideline. Each of these references will already have been noted within the text of the design guideline (e.g., as part of the discussion included in the introduction, discussion, or design issues sections), and assigned a reference number. A complete reference section is provided in chapter 14 of this document.

OTHER FEATURES

A glossary is provided in chapter 12. Technical words and phrases are defined in the glossary and listed in the index (chapter 16). Abbreviations are provided in the glossary. Also, equations are numbered sequentially and listed separately in chapter 11 of this document.

Additional reference materials are also included. A summary of relevant U.S. Department of Transportation (USDOT), Society of Automotive Engineers (SAE), and ISO documents is provided in chapter 15.

CHAPTER 2: GENERAL ISSUES IN ICON DESIGN

GENERAL DEVELOPMENT PROCESS FOR IN-VEHICLE ICONS

Introduction: Reference 1 provides a literature review of icon design principles and design practices and concludes that a chief problem in the development of most icons is the lack of a systematic, rigorous design process. Reference 2 (from ISO TC 145/SCI DIS 7001) provides a procedure for the development of public information symbols that can be useful for developing in-vehicle icons. The design guidelines below have been adapted from this procedure.

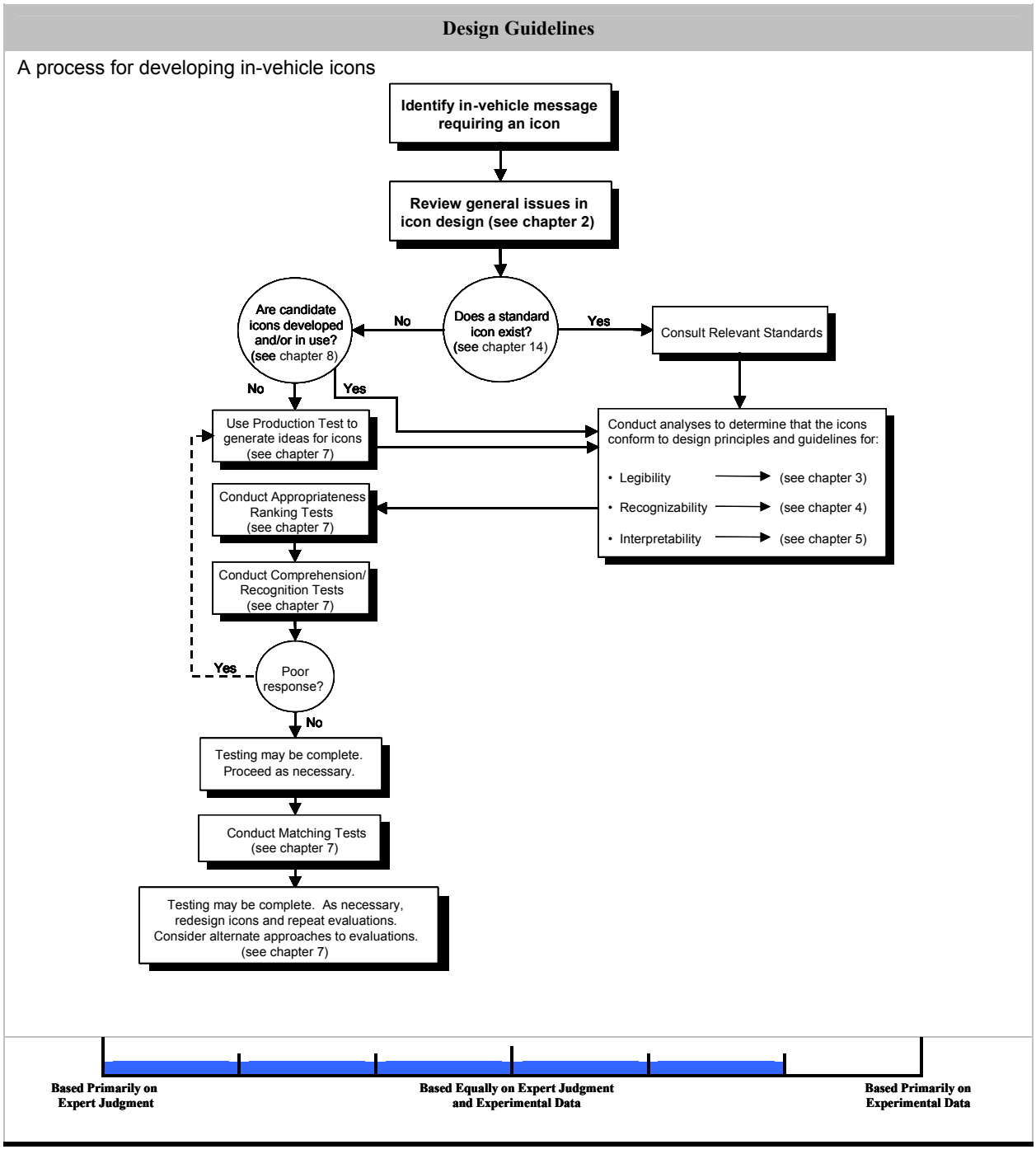


Figure 2-1. General Development Process for In-Vehicle Icons

Discussion: The icon development process outlined on the previous page provides a framework for icon design that has been organized and used by ISO and is consistent with good design and evaluation practices. The empirical portions of the guideline have been suggested in a number of data sources (e.g., references 2 and 3), while the analytical aspects are consistent with a number of comprehensive sources in the icon development domain (e.g., references 4 and 5).

Evaluating icons refers to the process of determining that an icon, or a set of integrated icons, meets specific criteria in areas such as legibility, recognition, interpretation, and driver preferences. Developing useful and effective icons requires evaluation. A rigorous and iterative evaluation phase in icon design increases the likelihood that the implementation of the icon in the in-vehicle environment will improve driving and system performance and not degrade driver safety.

General design principles for the design of in-vehicle icons provide important information that will increase the effectiveness and utility of icons. However, they represent only a necessary first step, and cannot take the place of empirically assessing the utility of a particular icon. In particular, such principles cannot always consider issues such as the driving context, different user groups of icons, or driver workload in selecting icons. That is, using general design principles alone cannot assess "specific effectiveness with the potential user group" (reference 6). Without research, icon development becomes little more than an intuitive approximation of what constitutes a good design, and lacks the confidence that can be obtained by empirical validation.

Design Issues: The development process for in-vehicle icons should reflect the specific needs, goals, and constraints associated with individual design efforts. Thus, individual icon design efforts may require additional tests, design criteria, or consideration of other development issues.

Cross References:
Chapter 3: Icon Legibility; Chapter 4: Icon Recognition; Chapter 5: Icon Interpretation; Chapter 6: The Auditory Presentation of In-Vehicle Information; Chapter 7: Evaluating In-Vehicle Icons; Chapter 8: Icon Collection

References:

1. Carney, C., Campbell, J. L., and Mitchell, E. A. (1998). *In-vehicle display icons and other information elements. Task A: Literature review* (FHWA-RD-98-164). Washington, DC: Federal Highway Administration.
2. Zwaga, H. and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.
3. Edworthy, J. (1994). The design and implementation of nonverbal auditory warnings. *Applied Ergonomics,* 25(4), 202-210.
4. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
5. International Organization for Standardization (ISO) 3461-1. (1988). *General principles for the creation of graphical symbols, Part I: Graphical symbols for use on equipment,* Geneva, Switzerland: ISO.
6. Collins, B. L. (1982). *The development and evaluation of effective symbol signs*. Washington, DC: U.S. Department of Commerce (NBS Building Science Series, 141).

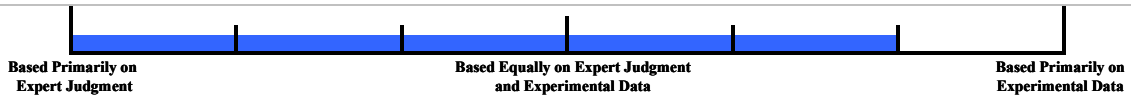
WHEN TO USE ICONS

Introduction: This section considers the criteria and issues that should be considered when determining whether an icon is the appropriate display element to use for an in-vehicle message. Determining when to use an icon is an extremely important design decision. In many instances, the use of an icon, instead of text, may be preferable. The design guideline lists several instances for which this may be true.

Design Guidelines

Use icons when:

- Quick and accurate recognition of a message is necessary (e.g., warnings).
- Displaying visual or spatial concepts (e.g., augmented signage).
- The driver will be performing a visual search of alternatives (e.g., motorist services information).
- The amount of space on the display is limited and presenting the information textually will take up more space than is available.
- One already exists and has a generally accepted meaning.



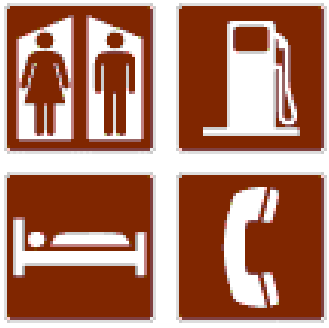
Icon Design Issue	Do This...	...Not This
Quick and accurate recognition is necessary		
Displaying visual or spatial concepts		
Presenting a set of alternatives		

Figure 2-2. Examples of the Appropriate Use of Icons

Discussion: Well-designed symbols are generally recognized more accurately and quickly than similarly worded signs (reference 1). Research performed in reference 2 compared subjects' ability to interpret the meaning of symbol and word highway signs. Subjects were asked to match a text sign to one of nine symbol signs they were shown on a following film segment. The results of this research showed that, overall, people were able to more accurately match symbol signs than they were word signs. Also, 65 percent of the subjects reported that the symbol signs were easier to match. Reference 3 found similar results. The researchers investigated subjects' ability to correctly identify word and symbol signs and found that they were able to more accurately identify the symbol signs. Reference 4 gives three reasons for this: (1) icons are more visually distinct than words; (2) visual symbols have names that we remember along with them, thus they are stored as both visual and verbal memories whereas text labels are stored only verbally; and (3) visual images are stored in memory in several forms and are tightly linked to one another and to other forms.

Another reason to use icons is that they can be presented in a much more spatially condensed form (references 5, 6, and 7) than can most text-based messages. This is especially important to consider when designing in-vehicle displays where the amount of room available is extremely limited. Road signs also have a limited amount of space for presenting information, and must take advantage of the fact that more information can be presented to the driver via icons and symbols than can be presented textually. Research in this domain has shown that symbols can be recognized more rapidly and are legible at greater distances than information presented in other formats (references 8 and 9).

Design Issues: Research has shown that while well designed symbols perform better than text (reference 1), poorly designed symbols do not (reference 5). Care should be taken to ensure that the symbols used are effective and that comprehension levels are high. Therefore, extensive testing should be done (such as that described in chapter 7 of this document) on every newly developed symbol, and even on some of those already in existence, when comprehension levels do not meet the ISO standard of 66 percent (reference 10).

Cross References:
Ways to Use Icons, p. 2-6

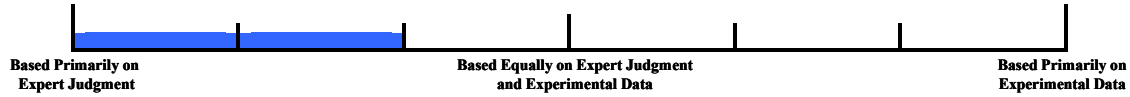
References:
1. Edworthy, J., and Adams, A. (1996). *Warning design: A research prospective*. London, U.K.: Taylor and Francis.
2. King, L. E. (1971). A laboratory comparison of symbol and word roadway signs. *Traffic Engineering and Control,* 12, 518-520.
3. Walker, R. E., Nicolay, R. C., and Stearns, C. R. (1965). Comparative accuracy of recognizing American and international road signs. *Journal of Applied Psychology,* 49(5), 322-375.
4. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
5. Zwaga, H. J., and Boersema, T. (1983). Evaluation of a set of graphic symbols. *Applied Ergonomics,* 14(1), 43-54.
6. Rohr, G., and Keppel, E. (1984). *Iconic interfaces: Where to use and how to construct human factors in organisational design and management*. The Netherlands: North-Holland.
7. Hemenway, K. (1982). Psychological issues in the use of icons in command menus. *Proceedings of the CHI 1982 Conference on Human Factors in Computer Science* (pp. 20-23). New York: Association for Computing Machinery.
8. Ells, J. G., and Dewar, R. E. (1979). Rapid comprehension of verbal and symbolic traffic sign messages. *Human Factors,* 21(2), 161-168.
9. Jacobs, R. J., Johnston, A. W., and Cole, B. L. (1975). The visibility of alphabetic and symbolic traffic signs. *Australian Road Research,* 5(7), 68-86.
10. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed materials* (pp. 277-297). New York: J. Wiley & Sons.

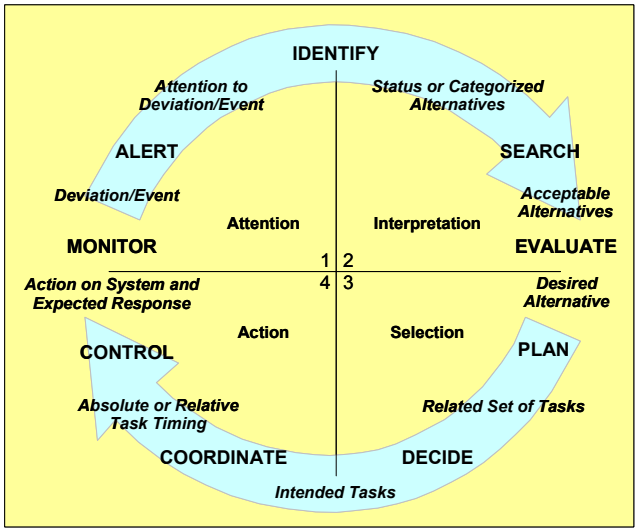
WAYS TO USE ICONS

Introduction: Icons may be used in a wide variety of ways to facilitate interaction with an in-vehicle information system (IVIS). Icons may alert drivers and guide their attention to a deviation or event. They can identify system status or acceptable alternatives, or support comparisons for selecting among alternatives. In addition, icons can help drivers take appropriate actions when used to label controls. Each of these general information processing functions has different icon-design requirements.

Design Guidelines

Information Processing Element	Potential Icon Applications	Examples	Important Guideline Topics To Consider for Effective Icon Design
Attention: Verifying process proceeds according to plan and directing attention to deviations	Icons that provide cautions and warnings	Collision avoidance Icy road warning	Augmenting icons with auditory information (p. 6-2) Flash rate (p. 4-8) Conveying urgency with icons (p. 5-14) Enhancing icon interpretation with color (p. 5-12)
Interpretation: Identifying a status or scanning potential alternatives	Icons that highlight changes in system state	Distance remaining for route Toll cost	Enhancing icon interpretation with text labels (p. 5-2) Conveying system status with icons (p. 5-10) Enhancing icon interpretation with color (p. 5-12)
Selection: Comparing alternatives, determining the effect each will have on the end goal, and choosing one to meet those goals	Icons for trip planning and route selection	Congestion related delay Hotel costs and availability	Identifying icons as part of a group (p. 5-8) Enhancing icon interpretation with color (p. 5-12)
Action: Selecting system functions and timing tasks to achieve an end goal	Icons that label controls and identify system features	Select route Retrieve message	Conveying the effect of actions with icons (p. 5-6) Identifying icons as part of a group (p. 5-8)





The figure to the left shows nine Infrastructure Processing Elements (IPE) that define the information requirements of a driver interacting with an IVIS device. These elements comprise a decision cycle represented by the circle. Between each IPE, phrases in italics identify a knowledge state that acts as the input to one element and the output of the previous element. Together, the nine elements describe the range of information-processing activities supported by IVIS messages. The decision cycle consists of four quadrants, with the IPEs within each quadrant serving a common purpose. The first quadrant, "Attention," involves detecting disturbances and deviations, and directing attention towards the disruption. The second quadrant, "Interpret," builds upon this to classify and understand attended inputs. The third quadrant, "Selection," uses this interpreted information to identify an appropriate course of action. The fourth quadrant, "Action," carries out the course of action. Each quadrant helps identify general design requirements for supporting driver decisions and the IPEs within each quadrant identify specific requirements

Figure 2-3. Information Processing Elements Used to Identify Icon Requirements

Discussion: The information processing perspective has long provided a useful tool to describe human-machine coordination (references 1, 2, and 3). Developed to describe human interaction with complex systems, Rasmussen's decision ladder provides one of the more detailed accounts of human-machine information processing. The decision ladder breaks the decision process into eight elements that describe the mental activities that link environmental cues to actions. More recently, reference 4 adapted Rasmussen's decision ladder and Miller's (references 5 and 6) information processing taxonomy to describe driver interaction with Advanced Traveler Information System (ATIS) devices. This description helped identify the driver limits and capabilities that are relevant for particular ATIS functions. This revised decision cycle consists of four quadrants, discussed on the previous page. IVIS messages may span more than one information processing element or quadrant of the figure, but these distinctions provide an initial guide for investing icon development resources.

Design Issues: The design requirements of an icon depend on the information processing it is meant to support. IVIS messages associated with "Attention" require an icon that can attract attention and direct it to the event of concern. Design issues include the size and placement of the icon, as well as the use of flashing and auditory cues to attract attention. IVIS messages associated with "Interpretation" require icons that can be easily linked to the potentially complex messages they seek to convey. Design issues include the use of text labels to avoid ambiguity and the need to use icons that are familiar to many people. IVIS messages associated with "*Selection"* require that icons enable drivers to clearly understand various options and alternate plans. Design issues include grouping icons so that differences can be easily seen and compared. IVIS messages associated with "*Action"* should indicate available options and indicate the consequences of pressing a button or selecting a menu option. Design issues include the need to convey the effect of an action or the sequence of activities that will result from enacting a system function. The figure on the previous page summarizes the four information processing functions and the associated design guidelines.

Cross References:
When to Use Icons, p. 2-4; *Flash Rate*, p. 4-8; *Chapter 5: Icon Interpretation*; *Augmenting Icons with Auditory Information*, p. 6-2

References:

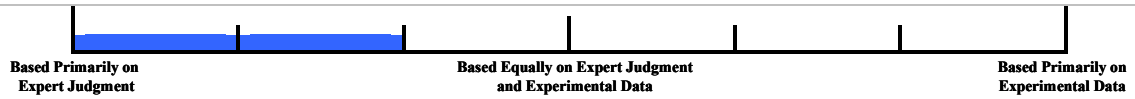
1. Broadbent, D. E., and Gregory, M. (1963). Division of attention and the decision theory of signal detection. *Proceedings of the Royal Society B*, 158, 222-231.
2. Neisser, U. (1967). *Cognitive psychology*. New York: Meredith Publishing Co.
3. Rasmussen, J. (1986). *Information processing and human-machine interaction: An approach to cognitive engineering.* New York: North-Holland.
4. Lee, J. D., Morgan, J., Wheeler, W. A., Hulse, M. C., and Dingus, T. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicles: ATIS and CVO functional description* (FHWA-RD-95-201). Washington, DC: Federal Highway Administration.
5. Miller, R. B. (1971). *Development of a taxonomy of human performance: Design of a systems task vocabulary* (AIR-72/6/2053-3/71-TRII). Washington, DC: American Institute for Research.
6. Miller, R. B. (1974). *A method for determining task strategies* (AFHRL-TR-74-26). Washington, DC: American Institute for Research.

TYPES OF VISUAL ICONS

Introduction: "Types of icons" refers to the classification of a particular icon based upon its resemblance to the message or referent. An icon can be classified three ways: image-related, concept-related, or arbitrary.

1. "Image-related icons" are highly pictorial representations of the object or act they represent.
2. "Concept-related icons" are based on an example or property of a real object or action.
3. "Arbitrary icons" do not resemble the object or action they represent, but become meaningful only through convention and education.

These three icon types have important and different implications for icon development and design.

Design Guidelines
"Image-related icons" are directly comprehended and should be used wherever possible.
"Concept-related icons" can be used if the user can be expected to comprehend the context in which the icon is presented.
"Arbitrary icons" can be difficult to recognize, hard to learn, and hard to remember. They should only be used if both context and special knowledge are present.


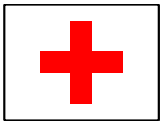
Icon Type	Key Examples	Other Examples	
Image-Related	 Fasten seat belt	 Telephone ahead	 Gas station ahead
Concept-Related	 Flash function on a camera or high voltage symbol in a power plant	 Curve signs	 Elevator
Arbitrary	 Addition symbol, first aid symbol, or international symbol for the Red Cross	 U.S. Postal Service	 Medical profession

Figure 2-4. Types of Icons

Discussion: Icons are visual representations or images used to symbolize an object, action, or concept. Several authors have classified icons into three different types: image-related (pictorial), concept-related (analogical), and arbitrary (see references 1 through 5). Image-related icons are highly pictorial representations of the object or act they represent. For these types of icons, meaning can be derived directly from the icon itself. For example, a seat belt icon usually appears whenever the ignition is started in a vehicle. This simply alerts drivers to the fact that they should be wearing their seat belt. This type of icon refers directly to the object it resembles and is therefore the easiest for people to remember and takes almost no effort to learn.

Concept-related icons are based on an example or a property of a real object or action. In most instances, the meaning of these types of icons will change depending upon the context that it is presented in. For instance, a lightning bolt symbol that is shown on a camera usually represents the flash function. However, when the lightening bolt symbol is seen in a different context, perhaps while touring an electrical plant, it might be indicating a high voltage area. Because the meaning of these icons changes depending on the context they are viewed under, they are slightly more difficult for people to learn.

Arbitrary icons do not resemble the object or action they represent, but become meaningful only through convention and education. A good example of an arbitrary icon is the Red Cross symbol, which generally refers to the concept of emergency first aid. To someone from another culture, however, it may have an entirely different meaning or it may have no meaning at all. For example, if you are not aware of this symbol's link to medicine or emergency first aid, you may simply see it as a symbol for addition or perhaps as a religious cross. However, if you are aware of this link, you may recognize it as the international symbol for the Red Cross. Therefore, it is necessary, in most cases, to have a particular knowledge base before being able to derive the correct meaning from these types of icons. This makes them the most difficult for people to learn and to remember.

Design Issues: These distinctions among icon types are important because they allow us to make predictions about an icon's interpretation and overall utility. Interpretation of an image-related icon may be high if the icon is a clear, straightforward representation of the message it represents. Interpretation of context-related icons may be high if the user understands the situation and condition associated with presentation of the icon. Interpretation of arbitrary icons requires both context and knowledge, yet they are very powerful and flexible.

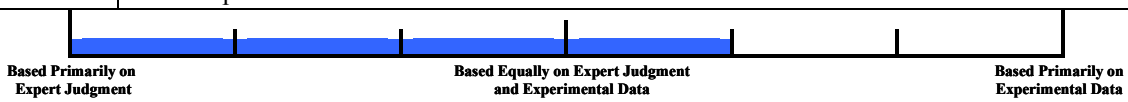
Cross References:
Ways to Use Icons, p. 2-6

References:
1. Lodding, K. N. (1983). Iconic interfacing. *IEEE Computer Graphics and Applications,* 3(2), 11-20.
2. Rogers, Y. (1989). Icon design for the user interface. *International Reviews of Ergonomics,* 2, 129-154.
3. Modley, R. (1976). *Handbook of pictorial symbols.* New York: Dover Press.
4. Beardon, C. (1992). Computer-based iconic communication. In K. Ryan and R. Sutcliffe (Eds.), *AI and cognitive science 1992* (pp. 263-276). New York: British Computer Society.
5. Bliss, C. K. (1965). *Semantography*. Australia: Semantography Publications.

COMPOSITION OF AN ICON

Introduction: An icon comprises several parts. These components work together to increase the likelihood that users will understand the icon.

Design Guidelines	
Border	• Use to show the extent of an icon (beginning and end).
Background	• Don't cover more than half the available area with objects. • Avoid patterns in the background. • Put the image clearly in front of the background. • Place objects in the center and the background around the periphery. • Use unsaturated, cool colors for the background, and saturated, warm colors for the foreground image. • Keep the background static; if anything blinks or moves, the viewer perceives it as a foreground image. • Limit the background image to a simple rendition of a recognizable, concrete object.
Element	• Use commonly accepted or standardized elements when possible. • Elements should reflect design principles described in chapter 4.
Symbol (Shapes)	• Circles should be used for presenting prohibition or mandatory information. • Triangles or diamonds should be used to present warning or cautionary information. • Squares or triangles should be used to present general information, instructions, or safe condition information.
Text Label	• Use only when necessary, especially when the icon is concept-related or arbitrary. • Keep text to no more than two-three words.



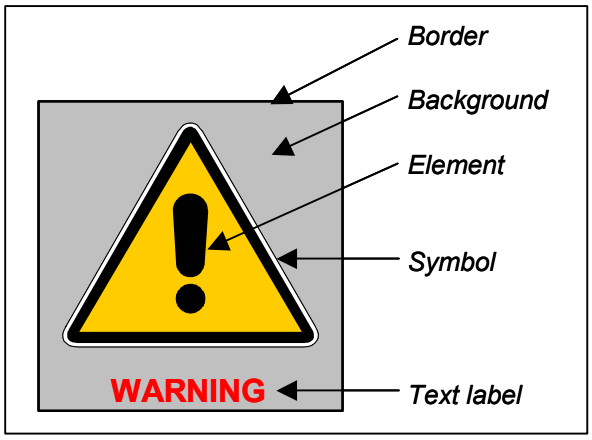


Figure 2-5. Key Components of an Icon

Discussion: Reference 1 has provided an overview of key parts of icons. Borders show the extent of an icon (i.e., where it begins and where it ends). This can be important to interactive systems that use icons as control buttons. In such instances, a border might help the user determine exactly where to click or point to select an icon. They also make icons appear orderly, consistent, and uniform. Borders can help clarify an icon's meaning if it resembles a familiar object (i.e., a book or an engine symbol). However, there are some drawbacks associated with using borders. They can make icons less distinctive, compete with the image, and limit the size of the image that can be used (see reference 2).

The use of a background is not always seen as being an important part of icon design. However, when used appropriately, backgrounds can help emphasize the image, group or classify icons, or show the state of an icon.

Shapes are also important for icon design because they can convey meaning. This is particularly true of traffic signs. According to the *Manual on Uniform Traffic Control Devices* (MUTCD), "STOP" signs are octagonal in shape; "YIELD" signs are equilateral triangles pointing downward; other regulatory signs are rectangular in shape with the longer dimension vertical; and warning signs are generally diamond-shaped. Having certain shapes designated for specific types of signs can help reduce both recognition and response times (references 3, 4).

Design Issues: Reference 1 suggests that presenting text labels in addition to an icon is a good idea when the icon is not obvious or if it is being presented for the first time. Research has shown that presenting the two together can increase comprehension and therefore overall effectiveness. For example, in reference 5, a study compared people's ability to navigate through a database using either pictorial icons, text labels, or a combination of the two. The results showed that subjects were able to reach the target object much quicker and with fewer steps in the icon plus text condition. Another study (reference 6) found similar results when it examined the role of graphics in the selection of items from a menu. Specifically, the study found that text plus graphics greatly reduced the number of errors in the selection of the correct item.

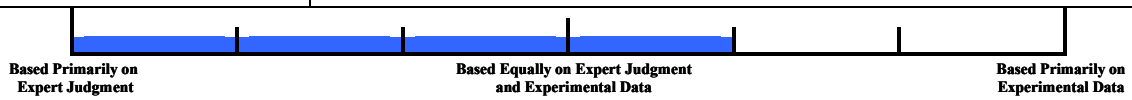
Cross References:
Level of Detail, p. 4-4; *Perceptual Principles of Icon Design*, p. 4-6; *Design of Prohibition Symbols*, p. 4-10; *Enhancing Icon Interpretation with Text Labels*, p. 5-2; *Identifying Icons as Part of a Group*, p. 5-8; *Conveying System Status with Icons*, p. 5-10

References:
1. Carney, C., Campbell, J. L., and Mitchell, E. A. (1998). *In-vehicle display icons and other information elements. Task A: Literature review* (FHWA-RD-98-164). Washington, DC: Federal Highway Administration.
2. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
3. ISO 3864. (1984). *International standard for safety colours and safety signs.* Geneva, Switzerland: ISO.
4. AS 2342. (1992). *Development, testing, and implementation of information and safety symbols and symbolic signs.* Sydney, Australia: Standards Australia.
5. Edigo, C., and Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing. *Human Factors in Computing Systems: CHI '88 Conference Proceedings*, 127-132.
6. Muter, P., and Mayson, C. (1986). The role of graphics in item selection for menus. *Behaviour and Information Technology,* 5(1), 89-95.

SEQUENCE OF ICON COMPREHENSION

Introduction: Sequence of icon comprehension refers to the perceptual and cognitive process by which users interpret the meaning of an icon. As discussed in reference 1, three stages appear to be associated with icon comprehension and use: legibility, recognition, and interpretation. Legibility reflects the relationships among the driver, the icon, and the environment; it is essential for the initial perception of the icon and includes parameters such as luminance uniformity, contrast, and icon size. Recognition reflects the relationships among the driver, the icon, and the other icons or visual display elements; it includes parameters such as whether or not the driver can identify the icon, especially in the context of the symbols and icons. Interpretation reflects the relationships among the driver, the icon, and the referent or message associated with the icon; it includes parameters such as whether the driver comprehends the meaning, intent, or purpose of the icon.

Design Guidelines	
Stage of Icon Comprehension	**Design Parameters to Consider**
Legibility	Determining the appropriate luminance uniformity in an icon; determining the appropriate contrast in an icon; determining the appropriate size of icon components; designing effective text labels, and the effects of color on icon legibility
Recognition	Level of realism, level of detail; perceptual principles of icon design; flash rate; design of prohibitive symbols; and driver acceptance of general versus specific icons
Interpretation	Enhancing icon interpretation with text labels; composition of text labels; conveying the effect of actions with icon; identifying icons as part of a group; conveying system status with icons; enhancing icon interpretation with color; conveying urgency with icons; and enhancing icon interpretation with shape



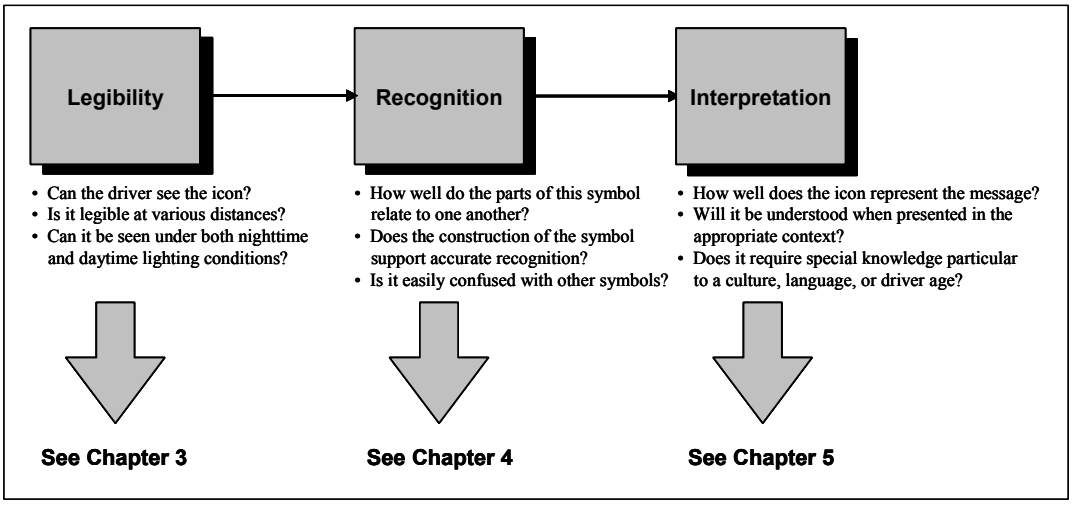


Figure 2-6. Sequence of Icon Comprehension and Use

Discussion: Developing effective icons and symbols requires a conceptual approach that applies a theoretical understanding of driver perception and performance (reference 2). Past research has demonstrated that if they are designed appropriately, visual symbols and icons can be a very effective way to communicate information to the driver. Less definitive information is available on *how* to design effective icons and symbols.

As shown in the graphic on the previous page, there seem to be three stages associated with icon comprehension and use. The first stage, legibility, reflects the relationship between the driver, the icon, and the environment. It includes basic issues such as whether or not the driver can see the icon, given the normal range of lighting and viewing conditions associated with driving. Legibility will depend on icon design issues such as luminance uniformity, contrast, icon size, text labels, and the effective use of color.

The second stage, recognition, reflects the relationship between the driver, the icon, and *other* icons or visual display elements. It includes issues such as whether the driver can identify the icon, especially in the context of other symbols and icons. For example, the standard icon for fuel depicts a gas pump. Accurate recognition of this icon would mean that the driver recognizes it as a gas pump. Recognition will depend on design issues such as level of realism, level of detail, perceptual principles of icon design, and flash rate.

The third stage, interpretation, reflects the relationship between the driver, the icon, and the referent or message associated with the icon. It includes issues such as whether the driver comprehends the meaning, intent, or purpose of the icon. For example, using the "gas pump" icon described above as an example, successful interpretation would mean that the driver understands what the icon's message is—the vehicle is low on fuel. Interpretation will depend on design issues such as the use of text labels, conveying the effect of actions with icons, identifying icons as part of a group, conveying system status with icons, the use of color in icons, and conveying urgency with icons.

Design Issues: After periods of exposure and use, drivers can learn to recognize virtually any icon; even ones that bear little relationship to their associated message. Thus, while even "bad" icons can eventually be effective, they may promote errors, require training, or involve extensive trial-and-error learning.

Cross References:
Chapter 3: Icon Legibility; *Chapter 4: Icon Recognition*; *Chapter 5: Icon Interpretation*

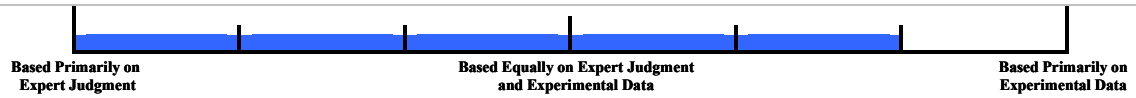
References:

1. Carney, C., Campbell, J. L., and Mitchell, E. A. (1998). *In-vehicle display icons and other information elements. Task A: Literature review* (FHWA-RD-98-164). Washington, DC: Federal Highway Administration.
2. Kantowitz, B. H. (1997, March). *In-vehicle information systems: Premises, promises, and pitfalls*. Paper presented at the Transportation Research Board Conference on Intelligent Transport Systems, Highway Safety and Human Factors, Washington, DC.

CHAPTER 3: ICON LEGIBILITY

DETERMINING THE APPROPRIATE LUMINANCE UNIFORMITY WITHIN AN ICON

Introduction: Luminance uniformity refers to the consistency of luminance values across an icon. Moderate nonuniformities in luminance may only lead to the driver's perception that the display is of poor quality. With great nonuniformities in luminance, however, there may not be sufficient luminance and contrast to ensure adequate legibility in certain areas of the display.

Design Guidelines
Provide no more than 33 percent element nonuniformity (within an individual element or segment).


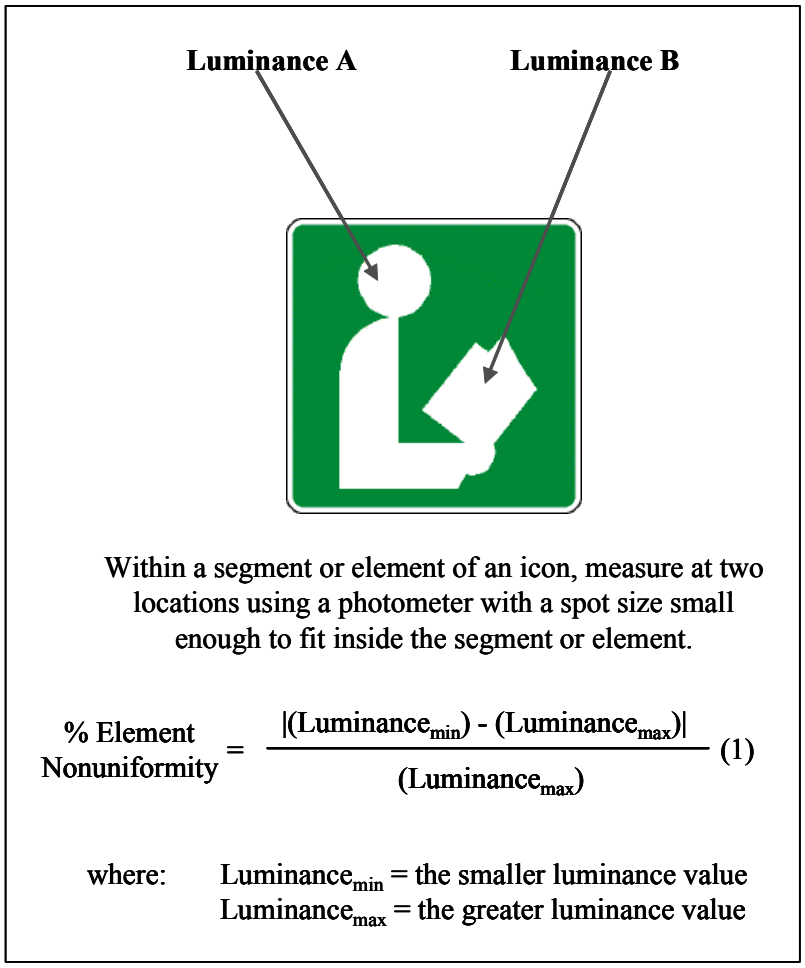


Figure 3-1. Measuring Luminance Nonuniformity

Discussion: *Threshold Luminance Discrimination Data.* Although observers in reference 1 could discriminate lights that differed in luminance by as little as 10 percent, these data were obtained when they were trying to detect a luminance difference between a background and a target under ideal laboratory conditions (also see reference 2). Thus, 10 percent represents a threshold luminance discrimination value and is far too conservative for IVIS use, in which the issue of concern is the driver's ability to notice luminance differences under normal driving or normal viewing conditions.

Tolerance for Luminance Variations. Reference 3 indicates that luminance in cathode ray tubes (CRTs) typically varies by as much as 37 percent and is either not noticed or is considered to be acceptable by observers. Reference 4 recommends that luminance variations remain below 50 percent. Reference 5 indicates that while the preferred limit for luminance variation across optical projection displays is 33 percent, an unacceptable limit is 66 percent.

Conclusions. The design guidelines reflect a composite of the information provided by references 3, 4, and 5. Specifically, luminance differences up to 37 percent are not always noticed by observers, and 33 percent represents a preferred limit, therefore 33 percent seems to be an acceptable limit for small-area luminance nonuniformities (i.e., within an individual element or segment). Both 50 percent and 66 percent have been suggested as absolute upper limits on luminance nonuniformities.

Design Issues: Luminance nonuniformities are generally caused by the display itself. In vacuum fluorescent displays (VFDs) being viewed directly, for example, these might be caused by poor phosphor distribution on the inside of the anodes, or by fluctuations in the power supply output.

Cross References:
Determining the Appropriate Contrast within an Icon, p. 3-4

References:
1. Mueller, C. G. (1951). Frequency of seeing functions for intensity discrimination at various levels of adapting intensity. *Journal of General Psychology, 34,* 463-474.
2. Boff, K. R., Kaufman, L., and Thomas, J. P. (1986). *Handbook of perception and human performance.* New York: J. Wiley & Sons.
3. Farrell, R. J., and Booth, J. M. (1984). *Design handbook for imagery interpretation equipment.* Seattle, WA: Boeing Aerospace Company.
4. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
5. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.

DETERMINING THE APPROPRIATE CONTRAST WITHIN AN ICON

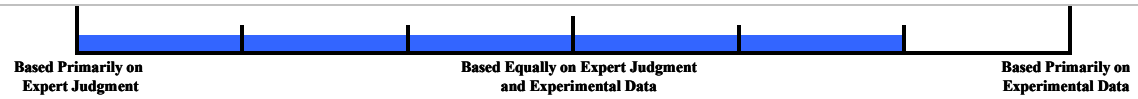
Introduction: Contrast refers to the relationship between the luminance of a symbol and the luminance of its background. Contrast requirements have not been empirically studied under a wide range of representative driving situations and conditions, thus few empirical data can be directly used to specify design guidelines.

We define contrast as a ratio between maximum and minimum luminance values, or: (2)

$$\text{Contrast ratio} = \frac{\text{Luminance}_{max}}{\text{Luminance}_{min}}$$

where:

Luminance_{max} = luminance emitted by the area or element of greater intensity
Luminance_{min} = luminance emitted by the area or element of smaller intensity

Design Guidelines
3:1 Minimum symbol contrast 7:1 Preferred symbol contrast


The figure below may be used to aid contrast measurements.

NOTE: The spot size of the photometer used to take luminance measurements must be small enough to fit inside the icon elements being measured.

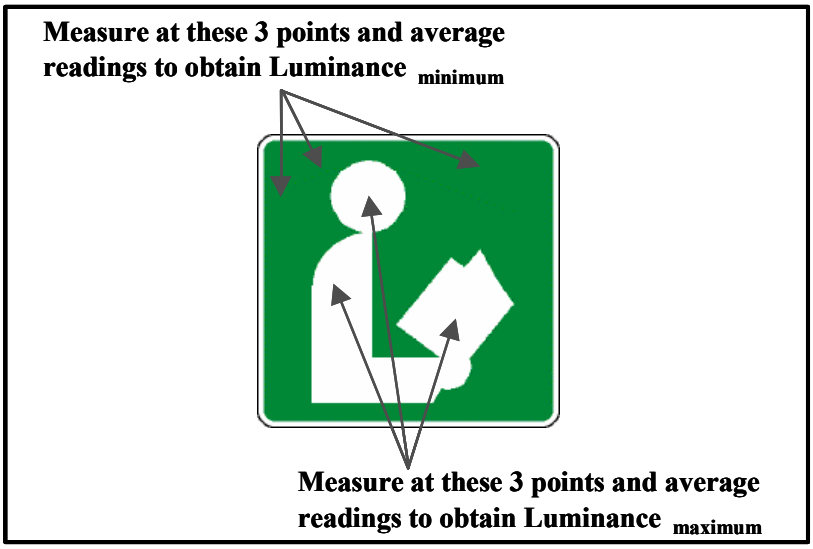


Figure 3-2. Example of Measuring Contrast

Discussion: Contrast requirements can vary greatly as a function of display medium (e.g., electronic display vs. hardcopy), viewing environment (e.g., low vs. high glare), and user characteristics (e.g., young vs. older drivers). Most human factors reference sources that provide contrast recommendations do not address the effects of these and other variables on contrast requirements. Reference 1 describes a series of studies investigating the legibility of displays, and concludes that contrast ratios of 10:1 to 18:1 are required for visual display terminal (VDT) displays. Reference 2 indicates that a contrast ratio of 10:1 has become "a generally accepted industrial standard for display design." Reference 3 suggests that a contrast ratio of 7:1 is preferred, but that 3:1 is required; the guidelines given here reflect the recommendations in reference 3. However, other data sources suggest that far less contrast may be adequate.

Daytime. An ambient background luminance of 2500 foot lamberts (fLs) is considered to be a representative "worst case" background luminance for daytime driving. Reference 4 indicates that symbol contrast of 1.2:1 is sufficient for young military pilots. In reference 5, contrast requirements for both younger and older subjects were investigated under laboratory conditions. The data from reference 5 indicate that 1.4:1 contrast may be sufficient for older drivers under those conditions.

Nighttime. In reference 6, contrast requirements for both younger and older subjects were investigated under low luminance laboratory conditions. The data obtained in reference 6 indicated that 2:1 contrast is required for older drivers under low luminance conditions; in this study, adequate legibility was not obtained at contrast levels below 2:1 (i.e., 1.25:1).

Design Issues: The contrast ratios provided above will lead to adequate legibility as long as other design parameters, such as icon size and luminance, are sufficient. Older drivers generally have poorer visual acuity than do younger drivers. Thus, the design guidelines specified above assume that, all other factors being equal, design objectives for contrast that meet the legibility needs of older drivers will always meet the legibility needs of younger drivers.

Cross References:
Determining the Appropriate Luminance Uniformity within an Icon, p. 3-2; *Determining the Appropriate Size of Icon Components*, p. 3-6

References:

1. Shurtleff, D. A. (1980). *How to make displays legible*. La Mirada, CA: Human Interface Design.
2. Smith, M. J., and Cohen, W. J. (1997). Chapter 50: Design of computer terminal workstations. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 1637-1688). New York: J. Wiley & Sons.
3. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
4. MIL-D-87213A. (1986). *Military specification displays, airborne, electronically/optically generated.* Washington, DC: U.S. Government Printing Office.
5. Blackwell, O. M., and Blackwell, H. R. (1971). Visual performance data for 156 normal observers of various ages. *Journal of the Illuminating Engineering Society,* October, 3-13.
6. Mourant, R. R., and Langolf, G. D. (1976). Luminance specifications for automobile instrument panels. *Human Factors,* 18(1), 71-84.

DETERMINING THE APPROPRIATE SIZE OF ICON COMPONENTS

Introduction: Size of icon components refers to the visual angle subtended (at the driver's eye) in minutes of arc, by either the symbol or the text that comprises an icon. Determining the adequate size for a legible icon is extremely important as the amount of space available for advanced in-vehicle display icons and other information elements is very limited.

Design Guidelines

- The visual angle of symbols contained within an icon:
  optimum visual angle = 1.43 degrees (85 arcmin.)
  minimum visual angle = 0.69 degrees (41 arcmin.)
- The visual angle of text labels contained within an icon:
  optimum visual angle = 0.40 degrees (24 arcmin.)
  minimum visual angle = 0.27 degrees (16 arcmin.)

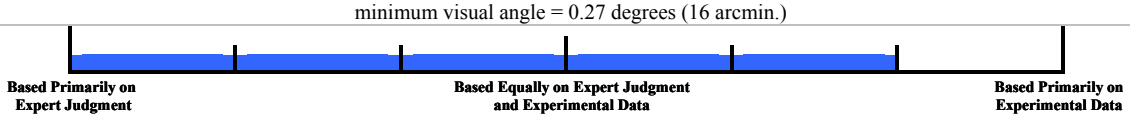


Table 3-1. Determining the Appropriate Size of Icon Components

If Known	Use These Formulas for Calculating These Unknowns		
	Visual Angle	**Symbol Height**	**Distance**
Distance and Symbol Height	$\text{Arctan}\left[\frac{\text{Symbol Height}}{\text{Distance}}\right]$ (3) or $\left[\frac{3438\ (\text{Height})}{\text{Distance}}\right] \div 60$ (4)	–	–
Distance and Visual Angle	–	Distance H [Tangent (Visual Angle)] (5)	–
Visual Angle and Symbol Height	–	–	$\frac{\text{Symbol Height}}{\text{Tangent (Visual Angle)}}$ (6)

where: Symbol Height = the height of the symbology
Distance = distance from viewer's eyepoint to the display
Visual Angle = angle in degrees
Height and Distance use the same unit of measure

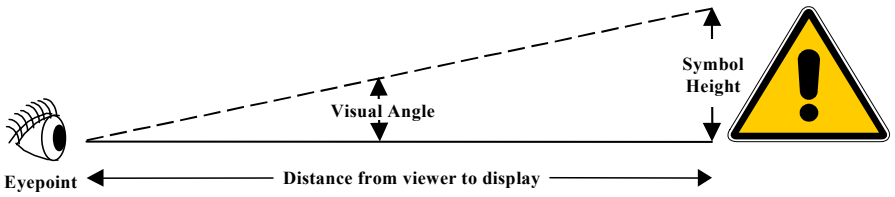


Figure 3-3. Relationship Between Viewing Distance, Symbol Height, and Visual Angle

Discussion: The design guidelines for symbol size are consistent with the recommendations made by reference 1, which were based on a variety of research related to detection and resolution thresholds. The maximum visual angle suggested (85 arcminutes) is aimed at ensuring conspicuity, while the minimum visual angle (41 arcminutes) simply ensures legibility. It is important to note that the recommendations made in reference 1, and therefore the guidelines on the previous page, are based on the assumption that the symbol will not be placed outside a 15-degree angular displacement from the central line of the normal direction of user's vision.

Design guidelines regarding the size of text labels is supported by reference 2, which recommends an optimum character height of 24 arcminutes of visual angle. In addition, references 3, 4, and 5 investigated symbology height requirements as a function of various levels of contrast and luminance. Considered as a whole, the empirical data from these studies indicate that: (1) critical symbology should subtend at least 20 arcminutes; (2) legibility begins to decrease at less than about 18 arcminutes; and (3) designers should avoid using symbology that subtends less than 16 arcminutes. Given the consistent and static nature of text labels for icons, the minimum visual angle of text labels (16 arcminutes) reflects these recommendations.

Reference 6 indicates that the minimum size of graphical symbols is $1/100^{th}$ their viewing distance, which corresponds to 0.57 degrees visual angle. Icons presented using a dot-matrix display technology (e.g., CRT or LCD) are typically 16x16 or 32x32 pixels in size (reference 7). Also, reference 8 notes that selecting an appropriate size for an icon depends on the input device used within the system. For example, icons that will be selected using a mouse or a track ball should be at least 20x20 pixels, and icons that will be selected using a stylus or a pen should be at least 15x15 pixels.

Design Issues: Older drivers generally have poorer visual acuity than do younger drivers. Thus, the design guidelines specified above assume that, all other factors being equal, design objectives for symbol height that meet the legibility needs of older drivers will always meet the legibility needs of younger drivers.

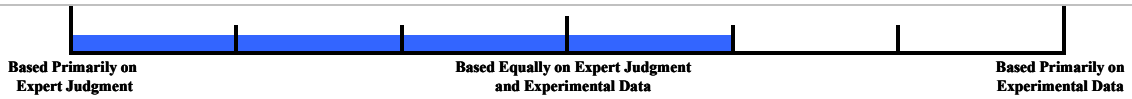
Cross References:
Determining the Appropriate Contrast within an Icon, p. 3-4; *Designing Effective Text Labels,* p. 3-8

References:

1. International Organization for Standardization (ISO)/TR 7239. (1984). *Development and principles for application of public information symbols*. Geneva, Switzerland: ISO.
2. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
3. Mourant, R. R., and Langolf, G. D. (1976). Luminance specifications for automobile instrument panels. *Human Factors,* 18(1), 71-84.
4. Howell, W. C., and Kraft, C. L. (1959). *Size, blur, and contrast as variables affecting the legibility of alpha-numeric symbols on radar-type displays* (WADC Technical Report 59-536). Wright-Patterson Air Force Base, OH: Wright Air Development Center (DTIC No. AD-232 889).
5. Giddings, B. J. (1972). Alpha-numerics for raster displays. *Ergonomics,* 15(1), 65-72.
6. ISO 3461-1. (1988). *General principles for the creation of graphical symbols, Part I: Graphical symbols for use on equipment.* Geneva, Switzerland: ISO.
7. Fowler, S. L., and Stanwick, V. R. (1995). *The GUI style guide*. New York: Academic Press.
8. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.

DESIGNING EFFECTIVE TEXT LABELS

Introduction: Text labels refer to words or phrases, as well as all other numerical and character symbols, provided as part of an icon that act to define or clarify its meaning.

Design Guidelines
• Text labels should be brief, no more than 2-3 words. • The type should be at least 0.27 degrees of visual angle (16 arcmin.); 0.40 degrees (24 arcmin.), maximum. • Use a clear and simple sans serif typeface such as Helvetica. Avoid using boldface, italics, underlining, or differences of color to emphasize words. • The space between lines should be at least 1/30 the line length. • Use both uppercase and lowercase letters rather than all of one or the other. • Character width-to-height ratios should be 0.6:1 - 1:1 (width:height). • Wider characters should be used as criticality increases. • If text must be compressed, compress the space between characters rather than the characters (1). • Use initial capital letters for multiword labels not incorporated in the symbol.


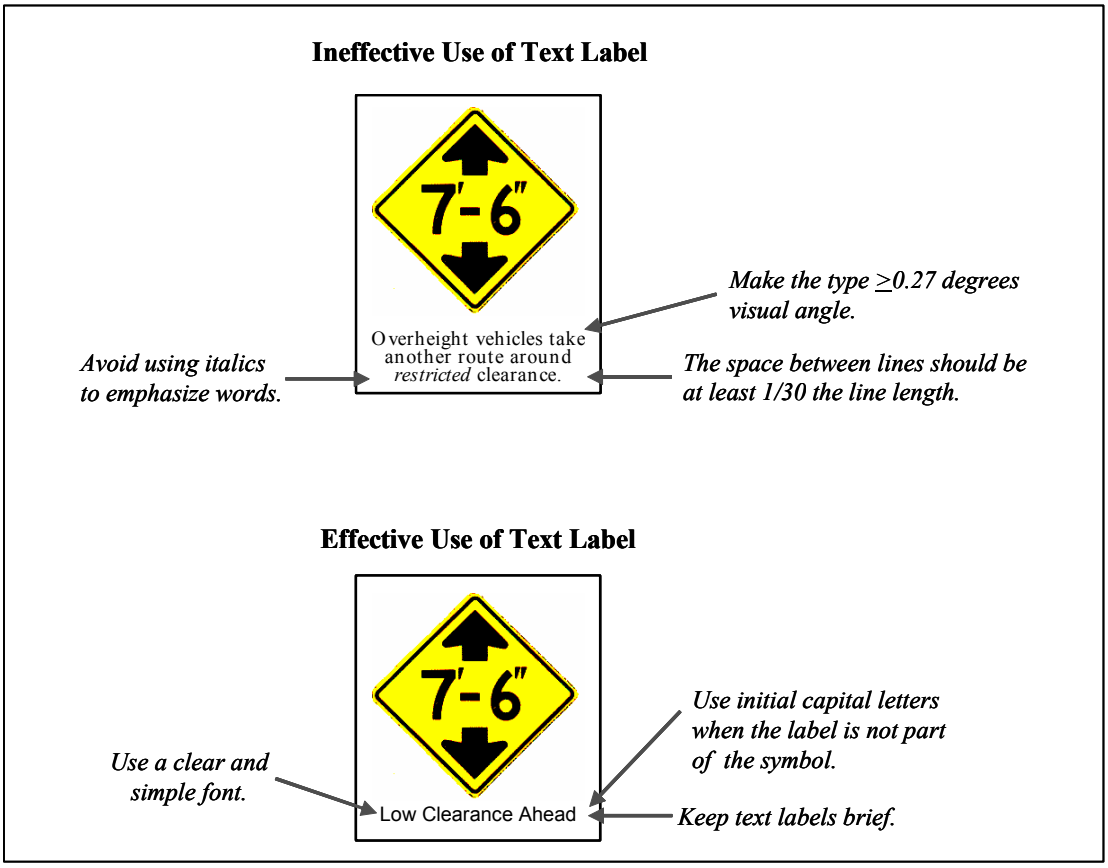


Figure 3-4. Schematic Examples of Text Labels

Discussion: Reference 1 studied the effect of character width and spacing on type legibility of warning labels. Pairwise comparisons were performed for every width and spacing combination. Results indicated that a reduction in character width had a more detrimental effect on legibility than inter-character separation. In addition, the study suggested that as character size increases, spacing may be decreased without a loss in readability.

Reference 2 suggests that presenting text labels in addition to an icon is beneficial when the icon is not obvious or if it is being presented for the first time. This reference provides several suggestions for successfully using text labels (see the "Design Guidelines" on the previous page).

Research indicates that presenting an icon and a text label can increase comprehension and therefore overall effectiveness. For example, a study comparing people's ability to navigate through a database using either pictorial icons, text labels, or a combination of the two discovered that subjects were able to reach the target much more quickly and with fewer steps in the icon-text combination condition (reference 3). Another study found similar results when examining the role of graphics in the selection of items from a menu. Specifically, the study found that text plus graphics greatly reduced the number of errors in selecting the desired item (see reference 4).

Design Issues: The use of text labels in icon design can lead to problems, however. First, text labels should be brief, containing no more than two or three words. However, not all icon concepts are amenable to such a succinct label. If not carefully chosen, a text label may mislead the user and reduce comprehension. Second, text labels reduce the universal nature of icons, as they necessarily reflect a specific language and/or culture. Third, text labels require additional display space. Such space might be better used to increase the size and understandability of the icon.

Older drivers generally have poorer visual acuity than do younger drivers. Thus, the design guidelines specified above assume that, all other factors being equal, design objectives for icon text that meet the legibility needs of older drivers will always meet the legibility needs of younger drivers.

Cross References:
Composition of an Icon, p. 2-10; *Determining the Appropriate Size of Icon Components,* p. 3-6; *Enhancing Icon Interpretation with Text Labels*, p. 5-2; *Composition of Text Labels*, p.5-4

References:

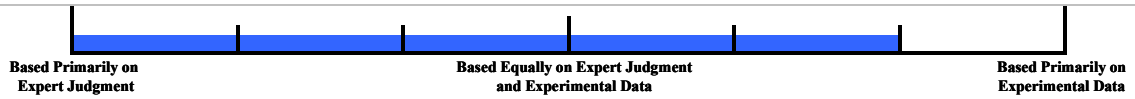
1. Young, S. I., Laughery, K. R., and Bell, A. (1992). Effects of two type density characteristics on the legibility of print. *Proceedings of the 32nd Annual Human Factors and Ergonomics Society*, 905-909.
2. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
3. Edigo, C., and Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing. *Human Factors in Computing Systems: CHI '88 Conference Proceedings*, 127-132.
4. Muter, P., and Mayson, C. (1986). The role of graphics in item selection for menus. *Behaviour and Information Technology*, 5(1), 89-95.

THE EFFECTS OF COLOR ON ICON LEGIBILITY

Introduction: Our perception of color is derived from variations in the wavelength or spectral composition of light. Color perception can be described in terms of three psychological dimensions: hue, saturation, and brightness. Hue is related to the dominant wavelength of the stimulus; saturation is somewhat more loosely related to the spectral bandwidth of the stimulus; and brightness is related to the luminance of the stimulus.

Design Guidelines

- Any reasonably visible color may be used to create icons as long as guidelines for symbol height and contrast are followed and population stereotypes are not ignored. However, highly saturated blue (i.e., approximately 450 nanometers) should be avoided.
- If colored lines are shown against a colored background, the color contrast between the elements should be a minimum of 100 E (CIE Yu'v') distances.



$$\Delta E\ (CIE\ Yu'\ v') = \left[\left(155 \left(\frac{\Delta Y}{Ym} \right) \right)^2 + (367\ \Delta u')^2 + (167\ \Delta v')^2 \right]^{0.5} \qquad (7)$$

where:

$\Delta E\ (CIE\ Yu'\ v')$	=	the color contrast metric
ΔY	=	difference in luminance between text (symbology) and background
Ym	=	the maximum luminance of text (symbology) or background
$\Delta u'$	=	difference between u' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)
$\Delta v'$	=	difference between v' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)

NOTE: The constants 155, 367, and 167 in equation 7 are empirically derived weights (reference 1).

Figure 3-5. Equation for Determining Color Contrast

NOTE: Reynolds 1 states, *"The discriminability of pairs of colors depends on their differences in chrominance and luminance. While an entirely satisfactory metric does not exist which combines these attributes into a single assessment of total color difference, an estimate can be derived by calculating the weighted difference between the locations of the colors in the 1976 Commission International de l'Eclairage Uniform Chromaticity-Scale (CIE UCS L*u*v*)."*

"Note that this estimate should be used only to ensure discriminability of colors of relatively high luminance. Severe nonlinearities in the UCS limit the usefulness of this metric for colors having small luminance differences. In addition, the specification of small color differences should be treated with caution due to the inherent lack of color uniformity on most CRTs."

Discussion: Despite well-established differences in visual sensitivity as a function of color (wavelength), there is no consistent, empirical evidence that color has a meaningful effect on legibility (references 1, 2, and 3), and, in principle, any reasonably visible color may be used as long as recommendations for symbol height and contrast are adhered to. It is recommended that a highly saturated blue be avoided because the central fovea is relatively insensitive to highly saturated blue (references 4 and 5); highly saturated blue has also been associated with "disruptions in accommodation" (reference 6).

Reference 4 has provided a metric for determining symbol colors to maximize legibility for symbols of relatively high luminance. This metric, E (CIE Yu'v'), which is shown in the figure, is derived from the 1976 CIE UCS color diagram (CIE UCS). Although the metric does not combine the different attributes of color into a single assessment of total color difference, it provides a useful estimate of color contrast. Reference 4 indicates that for legibility of colored symbols on a colored background (with relatively high luminance conditions), the colors should differ by a minimum of 100 E (CIE Yu'v') distances. If the formula is applied to figures and backgrounds that differ negligibly in u' and v', this value corresponds to approximately 80 percent luminance contrast, which is rather high in comparison with traditional contrast recommendations.

Design Issues: Although E (CIE Yu'v') provides a seemingly adequate measure of color contrast, it is clear that much more research is needed in this area before specific recommendations regarding color contrast can be made for automotive applications. Reference 7 notes that different experimental tasks as well as different response measures need to be investigated.

Color contrast is a sufficiently difficult concept when applied to fixed-color, fixed-background displays; it becomes more complex when applied to displays such as automotive head-up displays (HUDs). With HUDs, the background for the symbology is dynamic and can be almost any color; background luminance can range from a fraction of a fL to 6,000 or more fLs, depending on conditions. In addition, the symbology is translucent, which means that both the background color and luminance combine with the symbology's color and luminance in an additive fashion. Color contrast, therefore, is not a very meaningful parameter when applied to HUDs.

It should be noted that, while color may have very little effect on icon legibility, it is extremely important for successful icon interpretation. Effective uses of color can help a driver to group information, code information, attract their attention more quickly, and facilitate interpretation via the use of population stereotypes. These issues and more are discussed in chapter 5.

Cross References:
Enhancing Icon Interpretation with Color, p. 5-12

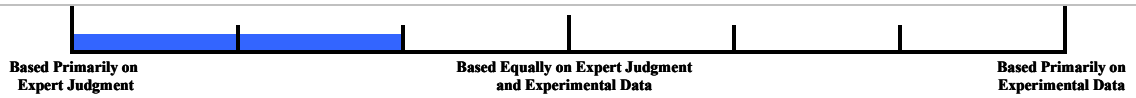
References:

1. Reynolds, H. N. (1971). The visual effects of exposure to electroluminescent lighting. *Human Factors,* 13(1), 29-40.
2. Post, D. L. (1985). Effects of color on CRT symbol legibility. *Society for Information Display 1985 Digest,* 196-199.
3. Christ, R. E. (1975). Review and analysis of color coding research for visual displays. *Human Factors*, 17(6), 542-570.
4. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
5. Murch, G. M. (1987). Visual perception basics. *Society for Information Display Seminar Lecture Notes,* 1, 2-1 - 2-36.
6. Donohoo, D. T., and Snyder, H. L. (1985). Accommodation during color contrast. *Digest of the Society for Information Display,* 200-203.
7. Decker, J. J., Pigion, R. D., and Snyder, H. L. (1987). *A literature review and experimental plan for research on the display of information on matrix-addressable displays.* Blacksburg, VA: Human Engineering Laboratory, Virginia Polytechnic Institute and State University.

CHAPTER 4: ICON RECOGNITION

LEVEL OF REALISM

Introduction: Level of realism refers to the relationship between the portrayed object or concept and the graphic means used to represent that object or concept. The graphic realism of an icon can have an impact on comprehension. Recognition can be facilitated for some icons by adding small details, while others are improved by a reduction in detail or by emphasizing important features. Only details that increase symbol recognition and comprehension should be included. Details that detract from recognition and comprehension should be omitted.

Design Guidelines
• For general or abstract concepts, less detailed symbols such as caricatures or silhouettes are most appropriate. • When several symbols have the same general shape or profile, detail is necessary to make them distinct from one another. In this case, they may be best portrayed using a simplified drawing. • For small, familiar symbols with a distinct profile, use an outline. However, when the symbol is too thin to be recognized in this format, a silhouette is preferred.


Example	Level of Realism	Design Style	When to Use
	Simplified drawing	Simplified drawing with distinct interior details	For presenting complex symbols with small significant parts, especially when objects have similar profiles (e.g., mechanical or electrical devices)
	Caricature	Exaggeration of crucial details	For presenting symbols that have a small, crucial feature or for simplifying complex details
	Outline	Outline with only prominent details	For presenting small symbols that represent a familiar object with a distinct profile
	Silhouette	Shape filled with solid color contrasting with background	For presenting symbols that are too thin to show in outline format and for symbols that have a very distinct profile and do not require detail for recognition

Figure 4-1. Five Levels of Realism

Discussion: Reference 1 discusses five different levels of realism that can be used: photographic realism, simplified drawing, caricature, outline, or silhouette. Each of these styles has its place, where one may work better than another for conveying particular types of information. In the driving context, the more detailed styles, such as photographic and simplified drawings, are the least practical. The amount of information they attempt to display makes them less recognizable in the sizes necessary for display. The silhouette style is the simplest of the five styles and is the most common type used in road signs. It is likely that this style will also be the most effective for use in in-vehicle displays.

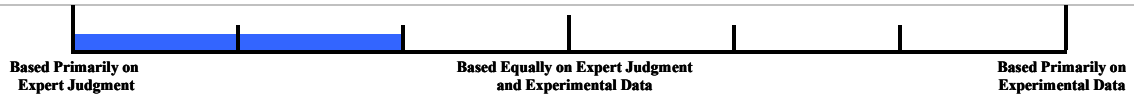
Design Issues: When icons are being designed as a set, it is important that the same level of detail or realism be chosen to portray the entire set. When this is not possible, the designer should choose both a primary style and an alternate that is most similar (i.e., caricature and outline). This will help to not only increase the ease with which they are recognized but to help the user see them as a set of related icons.

Cross References:
Level of Detail, p. 4-4; *Identifying Icons as Part of a Group*, p. 5-8

References:
1. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.

LEVEL OF DETAIL

Introduction: Level of detail refers to the amount of detail necessary for recognition of a symbol. Only those details that contribute to the meaning of the symbol should be included, while those that distract from the true goals of recognition and comprehension should be omitted. A significant detail refers to a symbol element that would reduce icon recognition and comprehension if removed.

Design Guidelines
• Design symbols on a 20 x 20 unit grid, making sure that no significant detail is smaller in size than 1 square unit (references 1 and 2). • Lines and other continuous aspects of the symbol do not need to span one grid square. • Significant details within a symbol should subtend, at a minimum, 3 degrees of visual angle (reference 3). • Line thickness for a significant detail should subtend, at a minimum, 2 degrees of visual angle (reference 3).


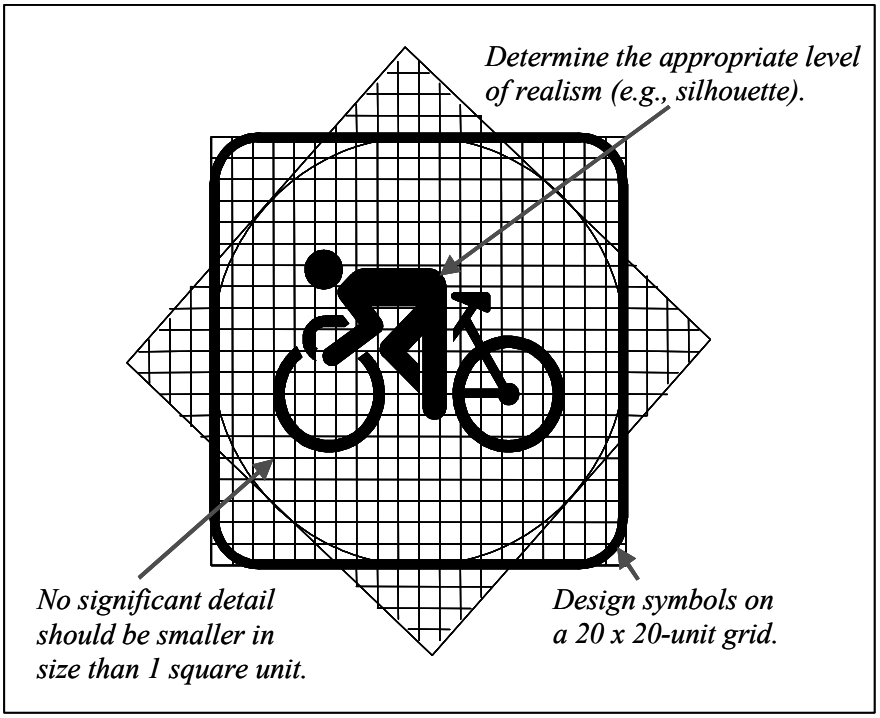


Figure 4-2. Example of Appropriate Level of Detail

Discussion: Icons should be designed with the appropriate level of detail. Including details that are necessary for discriminability can make objects much easier to recognize. However, including excessive amounts of detail simply creates clutter and can contribute to driver distraction. Therefore, care should be taken to omit any unnecessary details from the design.

To ensure that the level of detail is appropriate, references 1 and 2 suggest that the design of symbols should take place on a 20 x 20-unit grid; significant details should be no smaller than one square unit. This simple method can help designers adjust the level of detail of a symbol so that it is less likely to distract the driver or clutter the display.

Design Issues: There are several instances in which it may be necessary to increase the size of significant details within an icon: (1) when an icon is particularly important, such as in the case of warnings of imminent danger; (2) when icons suffer from unavoidable design deficiencies, such as poor color combinations, lack of adequate illumination, or excessive complexity; and (3) when it is important that the icon be noticed against a visually complex background.

Cross References:
Determining the Appropriate Size of Icon Components, p. 3-6; *Level of Realism*, p. 4-2

References:

1. International Organization for Standardization (ISO) 7001. (1990). *Public information symbols.* Geneva, Switzerland: ISO.
2. AS 2342. (1992). *Development, testing, and implementation of information and safety symbols and symbolic signs.* Sydney, Australia: Standards Australia.
3. ISO/TR 7239. (1984). *Development and principles for application of public information symbols*. Geneva, Switzerland: ISO.

PERCEPTUAL PRINCIPLES OF ICON DESIGN

Introduction: Perceptual principles of icon design refer to design recommendations based solely on the visual characteristics of the icon without reference to its intended function or meaning (see also references 1 and 2).

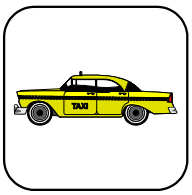
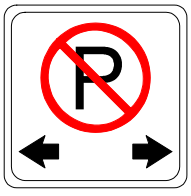
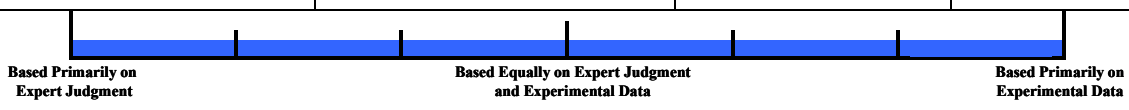
Design Guidelines			
Icon Design Parameter	**Recommendation**	**Do This…**	**…Not This**
Figure/ground relationship	Emphasize a clear, stable, and solid relationship between the elements of the symbol and its background		
Figure edges	Relatively solid shapes are better than thin or dotted-line edges unless the element in question depicts action or movement		
Closure	Use closed figures without discontinuous lines, outlines, or disjointed elements that can result in a fragmented figure		
Simplicity	Icons should be simple with only the necessary detail included; removal of these details should result in low recognition		
Unity	All parts of the symbol should be enclosed within a single boundary		
			

Figure 4-3. Perpetual Principles of Icon Design

Discussion: Many of the perceptual theories about how we decode and comprehend symbols have come from the ideas and experiments that were completed by such Gestalt psychologists as Kohler, Wertheimer, and Koffka. They were the first to discover that the determinants of shape and form are the *figures* in the visual field, which in turn are characterized by their *contour* (i.e., outline or boundary). This delineation of one part of the visual field from another is called the "figure/ground" phenomenon. The Gestalt psychologists also derived many of the principles that comprise the concept of "figural goodness," whereby the perceptual process of decoding incoming stimuli is enhanced by the inherent clarity and stability of the form (reference 4).

Easterby (references 2, 3, and 4) has conducted multiple studies that examine the figural aspects of symbols (e.g., the lines, curves, and graphics that make up a symbol) and using the principles of "figural goodness" to determine how they affect perception, recognition, understanding, and learning. He argues that the structural properties of a symbol are important determinates of its perceptibility and that they provide the contextual cues that define the meaning of a symbol (reference 1). These structural properties include aspects such as continuity, closure, symmetry, simplicity, and unity (reference 2).

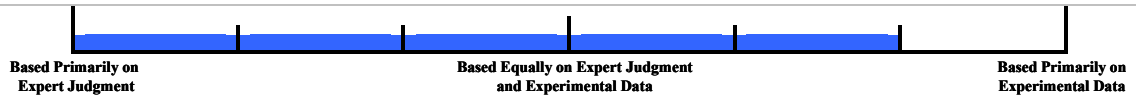
Cross References:
Composition of an Icon, p. 2-10; *Design of Prohibition Symbols*, p. 4-10

References:

1. Barnard, P., and Marcel, T. (1984). Representation and understanding in the use of symbols and pictograms. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 37-75). New York: J. Wiley & Sons.
2. Easterby, R. S. (1970). The perception of symbols for machine displays. *Ergonomics,* 13(1), 149-158.
3. Easterby, R. S. (1969). The grammar of symbols. *Print,* 13, 6.
4. Easterby, R. S. (1967). Perceptual organization in static displays for man-machine systems. *Ergonomics,* 10(1), 193-205.

FLASH RATE

Introduction: Flash rate refers to the rate at which a signal alternates between an illuminated and a non-illuminated state. References 1 and 2 provide several recommendations for the use of flashing signals.

Design Guidelines
• Flashing lights or icons should be reserved only for emergencies, because they have the potential to distract the driver. • Flash rates should be 3-10 per second (although 4 is best) with equal light/dark intervals. • Flash duration should be at least 0.05 second. • Only one signal should flash at a time. • The background should be steady when using flashing signals. • Flash rates should not be used as a visual coding method as only 2 levels can be discriminated on an absolute basis under optimum conditions.


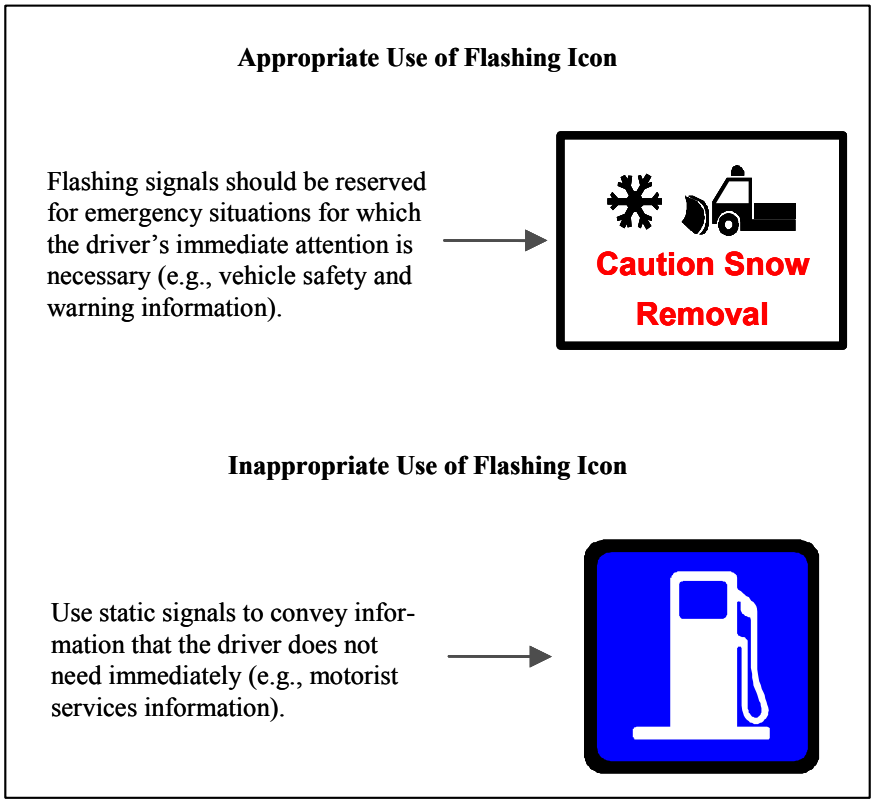


Figure 4-4. Schematic Examples of the Appropriate and Inappropriate Use of Flashing Icons

Discussion: According to reference 2, flash rates should be well below that at which a flashing light appears to be a steady light, which is approximately 30 times per second. Reference 1 recommends rates of about 3 to 10 per second, but states that 4 per second would be best. And reference 3 provides the same recommendation, adding that the flash duration should be at least 0.05 second.

Design Issues: Flashing signals are an excellent means for attracting the attention of the driver; therefore, it is extremely important that they be used only to signal emergency situations. Their ability to quickly gain and divert the driver's attention makes them an unsafe means for presenting noncritical or status information. It is also important to understand how the overuse of flashing signals can actually produce the opposite effect that may be desired. As more than one flashing light is introduced into the environment, the amount of time it takes a driver to react actually increases. Reference 4 found that, if even one irrelevant background light was flashing, reaction time would be greater than for a steady signal. Therefore, it is recommended that backgrounds remain steady when using a flashing signal and that only one signal flash on a display at a time.

Cross References:
Ways to Use Icons, p. 2-6*; Conveying Urgency with Icons*, p. 5-14

References:

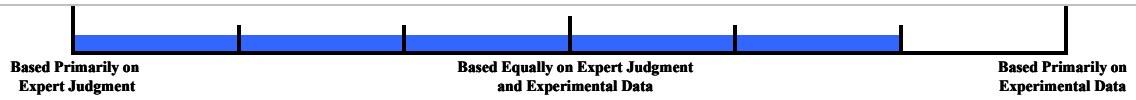
1. Heglin, H. J. (1973). *NAVSHIPS display illumination design guide: II. Human factors* (NELC/TD223). San Diego, CA: Naval Electronics Laboratory Center.
2. McCormick, E. J., and Sanders, M. S. (1982). *Human factors in engineering and design (5th ed.)* New York: McGraw-Hill.
3. Woodson, W. E., and Conover, D. W. (1964). *Human engineering guide for equipment designers (2nd ed.)* Berkeley, CA: University of California Press.
4. Crawford, A. (1963). Perception of light signals: The effects of mixing flashing and steady irrelevant lights. *Ergonomics*, 6, 287-294.

DESIGN OF PROHIBITION SYMBOLS

Introduction: Design of prohibition symbols refers to icons that present a specific action and communicate that the action should be avoided. Prohibition should be indicated by overlaying the action symbol with a red circle and 45° slash (top left to bottom right) or cross.

Design Guidelines

- Care should be taken not to obscure small details of the symbol with the slash or cross. When necessary, the symbol's placement or orientation may need to be changed. Modification of the slash may also be necessary to ensure the display of all important features. See the table below for alternative methods for indicating prohibition.
- Use full-length, solid slashes rather than partial or transparent ones. Slashes that appear in front of or behind the pictorial are preferred.
- Use a standard circle and 30°–60° slash to indicate prohibition. The circle and slash should be colored red for saliency.
- Use pictorials that do not contain too many small details small details are likely to be obscured by the circle or slash, making the pictorial ambiguous.
- Avoid using pictorials that show a negative consequence of an action. With the slash removed, the pictorial should portray a positive course of action.



Method	Example
Change slash angle to 30°–60°.	
Reverse direction of the slash.	
Reverse direction of the symbol.	
Displace slash to either side of center.	
Use a cross rather than a slash.	

Figure 4-5. Examples of Alternative Methods for Indicating Prohibition

Discussion: A glance legibility study (reference 1) asked participants to match an image they had been shown for either 1/10 s or 1/25 s to various traffic symbols on an answer sheet. Performance was much worse for those symbols with slashes either in front of or behind the pictorial than for those symbols with either a partial slash or no slash. It was concluded that the conventional circle and slash obscured portions of the pictorial and increased the overall complexity of the pictorial. Several recent studies, however, have found that people prefer symbols with the slash either in front of or behind the pictorial (references 1 and 2) and view these symbols as being more effective. Care must be taken when determining the placement of the slash, because a larger symbol may obscure a posterior slash, concealing that the symbol conveys a prohibition. Reference 3 hypothesizes that this may be due to viewers' familiarity with this format, since most symbols are currently being designed this way, or it could be due to the Gestalt principles of good figures.

The effectiveness of prohibition symbols is lowered by ambiguity, complexity, and confusability (reference 3). Ambiguity refers to symbols on which the slash has obscured some detail of the pictorial, making it possible for the symbol to have several different meanings. Complexity refers to symbols that attempt to include too much information (i.e., both an action and its consequence). Confusability refers to symbols that have unfamiliar or unusual features.

Design Issues: There are some ambiguities and inconsistencies across the literature on this topic. A red circle and slash is recommended by several standards documents (see references 4 and 5) for warning pictorial design. This design approach is also consistent with the perceptual principles discussed on page 4-6. However, research suggests that this format may actually obscure the symbol, making the icon much harder to recognize (references 1, 2, and 3). Reference 2 indicates that careful consideration of the placement of the pictorial is necessary. Potential solutions to the problem of obscuring the symbol include changing the orientation of the pictorial, modifying the pictorial so that all important features are displayed or, in some cases, rethinking the overall concept behind the symbol and redesigning it completely. Reference 6 presents designers with several alternative methods for indicating prohibition when the standard 45-degree top-left-to-bottom-right slash covers too much of the symbol.

Cross References:
Composition of an Icon, p. 2-10; *Perceptual Principles of Icon Design*, p. 4-6

References:

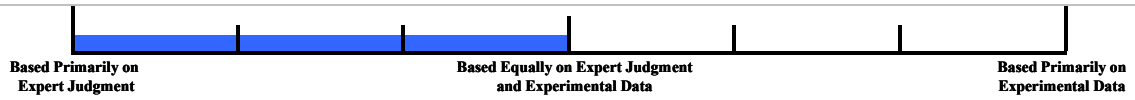
1. Dewar, R. E. (1976). The slash obscures the symbol on prohibitive traffic signs. *Human Factors,* 18(4), 253-258.
2. Glover, B. L., Magurno, A. B., Murray, L. A., and Wogalter, M. S. (1996). Pictorial negation: Preferences for different circle-slash variations. *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting*, 910-914.
3. Murray, L. A., Magurno, A. B., Glover, B. L., and Wogalter, M. S. (1997). Prohibitive pictorials: Evaluations of different circle-slash negation symbols. *International Journal of Industrial Ergonomics*, 22, 473-482.
4. American National Standards Institute. (1991). *American national standard for environmental and facility safety signs: Z535.2.* Washington, DC: Author.
5. ISO 3864. (1984). *International standard for safety colours and safety signs.* Geneva, Switzerland: ISO.
6. AS 2342. (1992). *Development, testing, and implementation of information and safety symbols and symbolic signs.* Sydney, Australia: Standards Australia.

DRIVER ACCEPTANCE OF GENERAL VERSUS SPECIFIC ICONS

Introduction: General vs. specific icons refers to the degree to which an icon provides information about a general class of in-vehicle messages vs. providing detail about the specific nature of an in-vehicle message. General icons are defined as icons that provide the driver with information about a broad driving situation or class of conditions without specifying detailed information about the situation or conditions. For example, a general icon for the message "crash warning" would indicate that a crash is imminent, but would not convey information regarding the precise nature of the projected crash (e.g., side, front, or rear crash). Specific icons are defined as icons that do provide more detailed information about a driving situation or conditions. For example, a family of specific crash warning icons could be used, with each icon describing the specific nature of the projected crash (e.g., side, front, or rear crash). The table below shows some examples of general and specific icons for key in-vehicle message categories**.**

Design Guidelines

- To minimize driver memory requirements and system complexity, general icons should be used as long as they do not negatively impact driver acceptance or performance. Well-designed general icons will be acceptable to most drivers under most driving circumstances
- The exception to this seems to be safety-related messages (e.g., collision avoidance icons). For safety-related messages, specific icons will provide higher levels of driver acceptance than do general icons.



MESSAGE	GENERAL ICONS	SPECIFIC ICONS
Trip navigation: Reduce speed		
Trip navigation: Lane blocked		
Trip navigation: Road closed		
Trip navigation: Emergency vehicle		
Trip navigation: Route guidance		
Collision avoidance system: Crash warning		
Vehicle condition monitoring: Urgent mechanical problem		
Vehicle condition monitoring: Vehicle maintenance required		
ATIS (motorist services): Lodging		
ATIS (motorist services): Food		
ATIS (motorist services): Gas		
ATIS (motorist services): Water recreation		

Figure 4-6. Examples of General and Specific Icons for Key In-Vehicle Message Categories

Discussion: Currently, the typical icon development approach entails the assignment of a specific icon to each driver message. For example, specific icons are used to depict low fuel conditions, weather conditions, and motorist services. The number of specific icons presented to drivers increases with the proliferation of In-Vehicle Information System (IVIS) devices. Unfortunately, this will place greater cognitive and memory burdens on the driver and may eliminate the advantages associated with using visual icons in the first place. In particular, working- and long-term memory capacities are quite limited (see reference 1), especially when retrieval strategies (chunking, rehearsal, auditory redundancy) strategies are not available (reference 2).

An alternative approach to using many specific icons to communicate individual messages is to use general icons to convey information about a class of conditions. Such an approach will work best in situations where the driver may not need detailed or specific information to understand the message sufficiently to take the appropriate driving action(s). The key advantage of general icons over specific icons is a reduction in the total number of icons that would be used within the in-vehicle environment.

Reference 3 investigated driver perceptions of the accuracy and acceptability of generic vs. specific icons for a range of in-vehicle message types. The effects of icon type (general vs. specific) were strongly mediated by the scenario descriptions given to subjects. Overall general icons were selected as the most accurate when subjects were presented with a general description of a particular driving scenario, and specific icons were selected as the most accurate when subjects were presented with a specific description of a particular scenario. However, for two message categories—collision avoidance and water recreation—specific icons were selected as the most accurate icons regardless of the scenario description. For the collision avoidance icons at least, this suggests that specific icons are desired where safety is an issue, perhaps because drivers want to have as much information as is available.

These general findings, however, should be considered in light of results from the study relating to the acceptability of general vs. specific icons. While the perceived accuracy of icons varied as a function of the scenario described to the subjects. High levels of acceptability were obtained for both the general and specific icons, regardless of scenario description. Specifically, the general icons resulted in 80 percent or higher levels of acceptance in 23 out of 23 messages in the general scenario description condition and in 20 out of 23 messages in the specific scenario description condition (exceptions were one of the three emergency vehicle messages and both vehicle maintenance messages). Therefore, it seems very clear that general icons are *capable* of meeting driver expectations and preferences for a broad range of IVIS messages.

Design Issues: Reference 3 only investigated driver acceptance of general vs. specific icons. Driver behavior and performance issues for the "general vs. specific" question remain to be investigated.

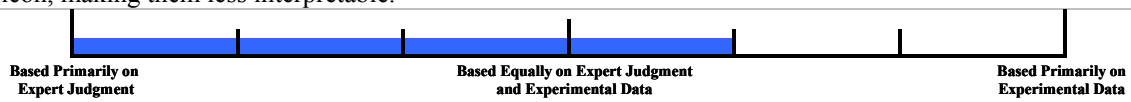
References:

1. Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review,* 63, 81-97.
2. Wickens, C. D. (1992). *Engineering psychology and human performance* (2nd Ed.). New York: Harper-Collins Publishers, Inc.
3. Campbell, J. L., Richman, J. B., Nakata, A., Simsek, O., and Schmidt, K. (2002). *In-vehicle display icons and other information elements. Task E, Experiment 6. General versus specific icons: Implications for driver acceptance of IVIS messages* (Final Report). Seattle, WA: Battelle Human Factors Transportation Center.

CHAPTER 5: ICON INTERPRETATION

ENHANCING ICON INTERPRETATION WITH TEXT LABELS

Introduction: Text labels refers to the use of text descriptions to enhance the interpretation of icons. Many icons are not immediately understood by drivers and text labels can facilitate the learning process.

Design Guidelines
Text labels should be considered when: • Icons are abstract and have no conventional or broadly understood meaning. • The icon represents a message that is particularly important or warns of a particularly hazardous situation. • The driver can safely spend one to three seconds interpreting the icon. • The task is complex.
Keep text labels concise (two to three words) and use them sparingly. Text labels reduce the space available for the icon, making them less interpretable.


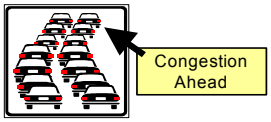
Icon	Icon with Text Label	Added Benefit of Label
		The synergy of the icon and embedded text label quantifies the degree of hazard and clarifies a potentially ambiguous image.
		Text label embedded in the icon clarifies an ambiguous icon by clearly identifying the type of vehicle.
		Text label beneath the icon clarifies the meaning of a complex combination of icons.
		Text label provided on demand through a cursor selection clarifies icon meaning for those unfamiliar with the system without cluttering the display for more expert users.
		Semitransparent labels provide a redundant indicator of system status.

Figure 5-1. Examples of Icons that Benefit from Text Labels

Discussion: Many icons may be misinterpreted because they have no commonly understood meaning and must be learned by the users (reference 1). This is particularly true of abstract icons that have no intuitive link to the message they try to communicate. The appropriate use of text labels can alleviate this problem. In fact, icons paired with text labels have been found to enhance performance, compared to icons alone, and enhance perceptions of usefulness, compared to text alone (references 2 and 3). Text labels can enhance interpretation by improving learning, identifying an appropriate action, and emphasizing hazards or important information. Even short text labels can help users learn icon meanings, which can be flawlessly recalled months after the initial exposure to the icon (reference 4). Text labels can also clarify a message and guide users to correct actions that might otherwise be obscured if the message were portrayed with only an icon or text (reference 5). Text labels also help clarify the uncertainty associated with color codes and shapes used to convey urgency. Used appropriately, text labels can address several problems of icon interpretation and provide benefits beyond those available with either text or icons alone.

Design Issues: Including a text label may not be possible without reducing the size of the icon and compromising icon legibility. With this design tradeoff in mind, three placement strategies can be considered to accommodate a text label. Most simply, the icon label can be placed at the bottom or top of the icon. This alternative consumes valuable space and may reduce the icon size, but it provides a clear identification of the icon. The label can also be devised so that it appears only on command, such as when it becomes activated by the cursor. This strategy does not impinge on display space, but novice users may not be aware that the icon label can be accessed through the cursor. More expert users may not need or want this feature, so allowing users to turn off the text would support novice users until they no longer need the icon definitions. Because this strategy requires cursor movement, it is not feasible for those icons that will be displayed while a vehicle is in motion. The label can also be directly superimposed on the icon itself. This strategy does not require additional display space, but it may interfere with icon legibility because the label may occlude critical elements of the icon. Making the lettering semitransparent will reduce the occlusion of the icon, but it will also reduce the legibility of the text. Reference 6 discusses several detailed strategies for combining text and graphical information effectively.

Cross References:
Designing Effective Text Labels, p. 3-8; *Composition of Text Labels*, p. 5-4; *Conveying Urgency with Icons*, p. 5-14

References:
1. Baber, C., and Wankling, J. (1992). An experimental comparison of text and symbols for in-car reconfigurable displays. *Applied Ergonomics*, 23(4), 255-262.
2. Wiedenbeck, S. (1999). The use of icons and labels in an end user application program: An empirical study of learning and retention. *Behaviour & Information Technology*, 18(2), 68-82.
3. Ramakrishnan, A. S., Cranston, R. L., Rosiles, A., Wagner, D., and Mital, A. (1999). Study of symbols coding in airway facilities. *International Journal of Industrial Ergonomics,* 25(1), 39-50.
4. Wogalter, M. S., and Sojourner, R. J. (1997). Comprehension and retention of safety pictorials. *Ergonomics*, 40(5), 532-542.
5. Edigo, C., and Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing. *Human Factors in Computing Systems: CHI '88 Conference Proceedings*, 127-132.
6. Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

COMPOSITION OF TEXT LABELS

Introduction: The content of text labels can affect the comprehension and interpretation of an icon's text label. Words should be chosen carefully to increase clarity and take into account the vocabulary level of potential users.

Design Guidelines

- Use explicit icon descriptions. Explicit text labels improve comprehension (references 1 and 2) and are perceived as conveying a more salient notification than non-explicit labels (references 2–4). In addition, precise descriptions allow the driver to judge when or where a situation will occur and thus aid in response preparation.
- Use nontechnical, common vocabulary (reference 5). Users will not know how to respond to a warning if they do not understand the text verbiage.

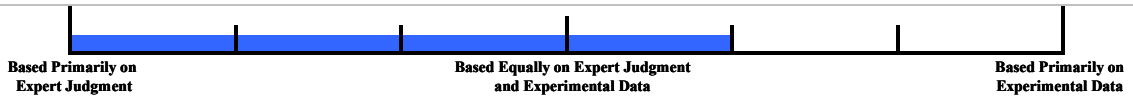


Table 5-1. Examples of Text Label Composition

Vague	Explicit	Technical	Nontechnical
Bump	Bump 100 Feet	Right Turn Prohibited	No Right Turn
Trucks Entering Highway	Trucks Entering Right	Alternator Malfunction	Charging System Failure
Congestion	Congestion 2 Miles	Reduce Velocity	Reduce Speed

Discussion: Research indicates that warning text explicitness and severity has an effect on the perceived level of hazard of product warning labels (references 1, 2, 3, and 4). For example, reference 2 examined the explicitness of warning labels on infant car seats. Subjects rated their perceived hazard, likelihood and severity of possible injury, and the intent to act cautiously. Results indicate that explicit warning labels increase the perception of possible hazards and injuries as well as ratings of cautious intent.

Reference 5 evaluated the comprehension of product warning labels, specifically the difference between "flammable" and "combustible." The study found that very few respondents knew the difference between the two terms, and most perceived the incorrect term as more hazardous. Similarly, terms used to describe driving situations may be misunderstood or ignored by drivers who do not comprehend the vocabulary used.

Design Issues: When selecting icon text wording, using more explicit labels describing severe consequences can increase warning compliance. However, to be effective, these descriptions must consider the users' vocabulary level. A compromise between terminology simplicity and precision must be made to increase comprehension.

For example, an icon alerting the driver to a malfunction of the vehicle's alternator can be described in a number of ways. A message such as "Engine Problem" may not be adequately explicit, while "Alternator Failure" may be overly precise and not understood by users who are not familiar with engine terminology. A compromise such as "Charging System Failure" may be sufficient.

Under elevated stress conditions, simple instructions should be provided to reduce cognitive burden and decrease reaction time.

Cross References:
Designing Effective Text Labels, p. 3-8; *Enhancing Icon Interpretation with Text Labels*, p. 5-2; *Enhancing Icon Interpretation with Color*, p. 5-12; *Conveying Urgency with Icons*, p. 5-14

References:

1. Laughery, K. R., Sr., and Stanush, J. A. (1989). Effects of warning explicitness on product perceptions. *Proceedings of the Human Factors Society 33rd Annual Meeting*, 431-435.
2. Trommelen, M. (1997). Effectiveness of explicit warnings. *Safety Science*, 25(1-3), 79-88.
3. Laughery, K. R., Sr., Rowe-Halbert, A. L., Young, S. L., Vaubel, K. P., and Laux, L. F. (1991). Effects of explicitness in conveying severity information in product warnings. *Proceedings of the Human Factors Society 35th Annual Meeting*, 481-485.
4. Laughery, K. R., Sr., Vaubel, K. P., Young, S. L., Brelsford, J. W., Jr., and Rowe, A. L. (1993). Explicitness of consequence information in warnings. *Safety Science,* 16, 597-613.
5. Main, B. W., Frantz, J. P., and Rhoads, T. P. (1993, July). Do consumers understand the difference between "flammable" and "combustible?" *Ergonomics in Design*, 1(3), 14-17.

CONVEYING THE EFFECT OF ACTIONS WITH ICONS

Introduction: Conveying the effect of actions with icons refers to the ability of an icon to help the driver anticipate the effect of selecting a particular system function or option.

Design Guidelines
• Show consequences of action with arrows, speed lines, or the ghosting of images. • Use sequence of images to convey simple transformations. • Consider animated icons for predrive applications to show complex multistep consequences.
Because of the distracting nature of animated icons, they should be used only rarely and with great caution.

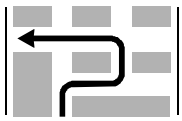
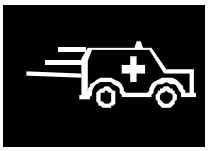
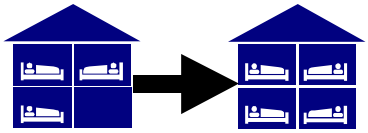
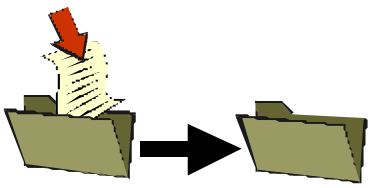

Icon Characteristic	Examples	
Arrows		
Speed Lines		
Sequencing of Images		
Ghosting		

Figure 5-2. Schematic Examples of Conveying Action

Discussion: Drivers may act upon icons that are used to identify system functions or options by pressing buttons or selecting menu items. Because these actions will change system modes or select a function, it is important that the icon show the driver the consequence of the action. The icon should show the "effect" or action that will occur when the control is actuated. When a symbol conveys action, it is important that the resulting action is the mechanism displayed. Actions can be displayed several ways: using arrows, speed lines, ghosting, or sequencing and animation (reference 1). Arrows indicate direction of change or movement, as in increasing volume or panning over an electronic map. Speed lines indicate activation, as in alarm or when sensors are enabled. Ghosting of an image shows an ordered sequence of states that will occur when the control is activated (reference 2) by using similar pictures with increasing levels of contrast—for example, the sequential position of a car on a route. Sequencing of images performs a similar function. By showing several images with connecting arrows, the consequence of an action can be shown, as in replying to an e-mail message (reference 3). Sequencing of images can be achieved with multiple small images shown at the same time or in animated sequences that show an icon changing over time. Each of these mechanisms for conveying action can help drivers understand the consequence of actions.

For these mechanisms to be successful, the icon must provide a context to highlight the relevant change. Some important elements of context include position, orientation, and similarities in content. Regarding position, drivers will generally perceive the images on the right as occurring after the ones on the left. Ghosted images can also be overlapped to show progression, with the previous states positioned behind the more recent. Icon orientation and similarities in content can also provide a context for showing change. By retaining key features or orientation of the icon in each of the multiple images, drivers will be able to identify how the elements of a sequence relate to each other.

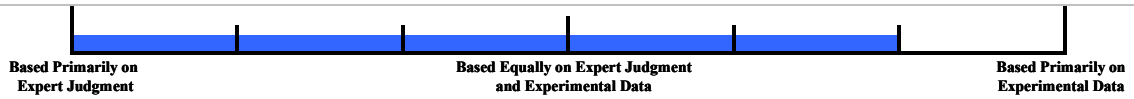
Design Issues: Animated icons can be a very effective mechanism for describing actions, but they are not appropriate for icons displayed while the vehicle is in motion. A constantly changing icon will distract driver attention from the roadway (reference 4).

References:

1. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
2. Tufte, E. E. (1997). *Visual explanations: Images and quantities, evidence and narrative*. Cheshire, CT: Graphics Press.
3. Dreyfuss, H. (1966). Case study: Symbols for industrial use. In G. Kepes (Ed.), *Sign, image, symbol* (pp. 126-133). New York: Braziller.
4. Theeuwes, J., Kramer, A. F., Hahn, S., and Irwin, D. E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science*, 9(5), 379-385.

IDENTIFYING ICONS AS PART OF A GROUP

Introduction: Grouping icons facilitates their identification as a set of related messages or similar commands. Grouping provides the driver with cues regarding system functionality and aids icon comprehension. Grouping can be accomplished using position, design, and labeling.

Design Guidelines
• Group icons based on the tasks that the user performs, rather than the architecture of the system. • Put related icons close together, especially those that are almost the same and those that are opposite. • If an icon fits into more than one group, duplicate it for each group. • As a last resort, label groups of icons or individual icons. • Put groups into separate boxes or windows. • Put borders or extra space between groups of icons. • Use a common color for background or icon elements to distinguish groups. • Within a group of icons, use similar style, level of realism, and level of detail. • Combine, transform, and include elements from other icons in the same group.


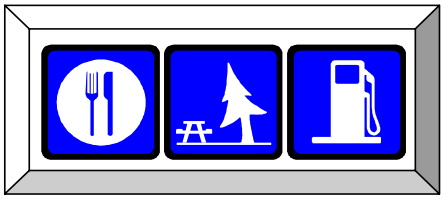
Description	Example
Common boundary identifies a group of icons as conveying warning information.	
Icons identified by a common level of detail and realism.	
Icons identified by a common style.	
Icons grouped by border, background, color, and style.	

Figure 5-3. Schematic Examples of Ways to Identify Icons as Part of a Group

Discussion: The context in which an icon is viewed provides a powerful influence on interpretation. Context can make an ambiguous icon meaningful. Identifying an icon as part of a group provides a context that can enhance icon interpretation, so it should be used when possible. Icons can be associated with a group by their physical location or proximity, icon style, level of detail, common borders or shapes, or by the use of color. These icon characteristics can be used to group icons according to three important criteria. The first grouping criterion is relative urgency or importance. This criterion has been used for many years to group highway signs. Highly urgent signs have a distinct shape and color as shown by the examples that show warning information. The second criterion is to identify icons based on whether they invoke system functions or display status information. Icons that can be used to invoke system functions should have common characteristics that suggest that they can be acted upon, such as a raised bezel suggesting a physical button that could be depressed. The third criterion that can be used to group icons is system function. These system functions should reflect driver needs, not system architecture (reference 1).

Relationships between groups can be conveyed through the use of common and distinct pictorial elements. For example, the use of similar shapes, colors, or borders can make icons appear related. This type of relation can be explained in terms of the Gestalt law of similarity, where there is a tendency for the visual system to group similar elements together as if they belong to each other. Organizing icons into groups according to their global features (i.e., shape, size, color) has also been shown to aid in discrimination. In reference 2, selection and response times for three different sets of icons were compared: a set in which the icons differed by their global features, a set in which the icons differed by their local features (i.e., lines and structures within the icon), and a word set. The results indicated that the global features of an icon elicited faster response times than local features. This phenomenon is referred to as the "global superiority effect" (references 3 and 4). In addition, reference 5 examined the use of color in icon design and found that color may be most useful for dividing icons into related subgroups and facilitating rapid identification.

Design Issues: Although labeling is suggested as a means for grouping icons (reference 6) and has been shown to be helpful for increasing comprehension and overall effectiveness (references 7 and 8), it is important that it be used as a last resort in this particular application. The most important reason for this is that design space may be extremely limited. Text labels must be kept brief with no more than one or two words, and not all icon concepts may be amenable to such a succinct label. If not carefully chosen, a text label may mislead the user and reduce comprehension.

Cross References:
Enhancing Icon Interpretation with Text Labels, p. 5-2*; Conveying the Effect of Actions with Icons*, p. 5-6; *Enhancing Icon Interpretation with Color*, p. 5-12; *Enhancing Icon Interpretation with Shape*, p. 5-16

References:
1. Lee, J. D. (1997). A functional description of ATIS/CVO systems to accommodate driver needs and limits. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 63-84). Mahwah, NJ: Lawrence Erlbaum Associates.
2. Arend, A., Muthig, K., and Wandmacher, J. (1987). Evidence for global superiority in menu selection by icons. *Behaviour & Information Technology,* 6, 411-426.
3. Pomerantz, J. R. (1983). Global and local precedence: Selective attention in form and motion perceptions. *Journal of Experimental Psychology: General,* 112, 516-540.
4. Wandmacher, J., and Arend, U. (1985). Superiority of global features in classification and matching. *Psychological Research,* 47, 143-151.
5. Davidoff, J. (1988). The colour of colour in visual displays. In D. J. Osborne (Ed.), *International reviews of ergonomics* (pp. 21-42). London: Taylor and Francis.
6. Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: J. Wiley & Sons.
7. Edigo, C., and Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing. *Human Factors in Computing Systems: CHI '88 Conference Proceedings,* 127-132.
8. Muter, P., and Mayson, C. (1986). The role of graphics in item selection for menus. *Behaviour & Information Technology,* 5(1), 89-95.

CONVEYING SYSTEM STATUS WITH ICONS

Introduction: Conveying system status with icons refers to changing icon appearance to convey changes in the system state. Frequently this will represent a simple on/off or active/inactive status, but it can include more complex multistate descriptions.

Design Guidelines
• Use a uniform decrease in contrast or a change of solid to dashed lines to convey on/off or active/inactive change. • Use an easily recognizable element and project changes upon it to convey system status that is described by multiple categories. • Represent status changes associated with changes in magnitude by increasing the number or size of well differentiated icon elements, rather than changing color or contrast. • Consider using text or numbers to represent changes of magnitude or categories.


Description	Examples	
On/off status indicated by decreased contrast and gray or dashed lines.	 Lodging available	 Lodging unavailable
Changes of categorical variables represented by changes projected on an easily recognizable element.	 Diesel available next exit	 Gasoline available next exit
Changes in magnitude represented by increasing the number of well-differentiated icon elements.	 High speaker volume	 Low speaker volume
Changes in magnitude represented by the addition of a numeric label.	 Five percent grade	 Ten percent grade

Figure 5-4. Examples of Conveying Status

Discussion: Icons can be used to convey many different types of information about system status. For the purpose of icon design it is useful to describe this information in terms of urgency and information type. Information type refers to three categories of information: binary, categorical, and magnitude. Binary state information describes system state in terms of being on/off or active/inactive distinctions. Icons convey this information best through global changes to the icon, such as a uniform change in contrast. Categorical information describes the availability of amenities or features of a system that are currently engaged. To convey this information, icons must provide a uniform context upon which changes can be made to indicate changes in the categorical information. For example, a "D" can be superimposed on a gas pump to indicate the availability of diesel gas. The gas pump icon provides the uniform context for the interpretation of the "D." Magnitude information refers to continuous or discrete information that can be ordered along a dimension such as small to large, low to high, or safe to dangerous (reference 1). To convey magnitude information, icons should increase the size or number of a distinct element of the icon. Numbers can be superimposed on the icon, particularly when precision is required. Color, angle, and contrast have a very limited ability to convey magnitude information (references 2 and 3).

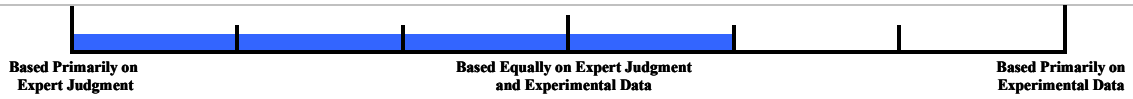
Design Issues: For icons to convey highly urgent signals clearly, differentiating state changes is particularly important. For example, a collision avoidance icon might indicate that the system is active and functioning properly. The same icon might be used to indicate a collision situation. This state change requires a more salient and recognizable indicator than an icon that shows whether the radio is on or off. To enhance the salience, the change should be accompanied by an auditory signal, the degree of change of contrast should be greater, and the color should emphasize the urgency of the signal.

Cross References:
Conveying the Effect of Actions with Icons, p. 5-6; *Enhancing Icon Interpretation with Color*, p. 5-12; *Conveying Urgency with Icons*, p. 5-14; *Augmenting Icons with Auditory Information*, p. 6-2

References:
1. Zhang, J. J. (1996). A representational analysis of relational information displays. *International Journal of Human-Computer Studies*, 45(1), 59-74.
2. Zhang, J. J., and Norman, D. A. (1995). A representational analysis of numeration systems. *Cognition*, 57(3), 271-295.
3. Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

ENHANCING ICON INTERPRETATION WITH COLOR

Introduction: Enhancing icon interpretation with color refers to how color can highlight information and enhance drivers' interpretation of icons; however, color can also confuse and mislead drivers if used incorrectly.

Design Guidelines
• Use color coding only when well-established conventions exist, such as temperature, dangerous situations, and permissiveness. • Use red to indicate highly urgent messages, yellow to indicate cautionary information, and green to indicate normal operations or safe conditions. • For temperature, use red for hot and blue for cold. • Arbitrary codes using color to convey meaning are likely to induce errors. • Color, such as red, can be used to enhance the relative salience of icons. Therefore, color choices should be made with respect to the relationship between messages (relative urgency of messages) and the relationship between messages and the background upon which they are presented. • Small spots of intense saturated color can convey information effectively. This requires a conservative use of these colors and the use of less saturated colors for backgrounds (reference 1). • Use shades of gray, rather than color, for showing quantity (reference 2).


Explanation	Example
Red enhances the relative salience of this icon and the strong population stereotype indicates a hazard.	
Yellow is often used for information such as caution or wait.	
Green is often used to indicate normal operations or to indicate permissible behavior.	
The small spots of intense color greatly enhance the effectiveness of this icon in identifying heavy traffic.	

Figure 5-5. Schematic Examples of the Use of Color in Icons

Discussion: The most common and consistent use of color for conveying information in the driving context is in traffic control devices. The use of green as permissive, amber or yellow for warning, and red for restrictive is almost universal. Red also has a powerful ability to convey urgency and hazard when used in warnings. Another important instance where color has come to hold a strong meaning is in the use of red for hot and blue for cold. These are two examples of "population stereotypes" or generally held expectations. When designing with color it is important to understand population stereotypes and conform to these expectations. Colors should not be used to convey meaning when there is not a well-established stereotype. Drivers will confuse the meaning of arbitrary color codes.

Beyond conveying specific meaning, color can also effectively highlight information and enhance interpretation of complex icons (references 1 and 2). Effective use of color in this role requires careful design that considers the use of color in relation to its context. Using color to highlight specific features or to enhance the salience of an icon requires a relatively muted and conservative use of color elsewhere. If all icons are designed to be relatively salient with the use of saturated colors, the resulting collection will have no highly salient icons. Similarly, highlighting a critical element of an icon with a saturated color requires that the other elements of the icon provide a background that does not compete with the highlighted details. Color choices should be made with a clear sense for the importance of elements within the icon and priority or urgency across a set of icons.

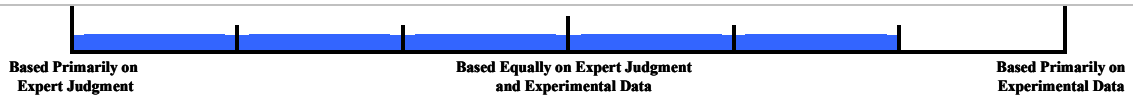
Design Issues: Color poses several problems for design. Some systems may not support color, so a monochrome design may need to be created. Gray scale can substitute for color, with the intensity of the gray conveying the meaning of the color. For example, if red were replaced by dark gray or black, then yellow and green would be replaced by corresponding lighter shades of gray. In addition, nearly 10 percent of the Caucasian male population and 4 percent of the non-Caucasian male population suffer from either color deficiencies or color blindness. The following color combinations should be avoided for these individuals: cyan and gray, yellow and light green, green and brown, red and black.

Cross References:
Ways to Use Icons, p. 2-6; *Determining the Appropriate Contrast within an Icon*, p. 3-4; *The Effects of Color on Icon Legibility*, p. 3-10; *Identifying Icons as Part of a Group*, p. 5-8; *Conveying Urgency with Icons*, p. 5-14; *Enhancing Icon Interpretation with Shape*, p. 5-16

References:
1. Tufte, E. R. (1990). *Envisioning information*. Cheshire, CT: Graphics Press.
2. Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

CONVEYING URGENCY WITH ICONS

Introduction: Conveying urgency with icons refers to adjusting icon characteristics so that they reflect the appropriate level of urgency of the situation. These adjustments enhance response speed and appropriateness.

Design Guidelines
To increase the perceived urgency of an icon: • Increase font size of text labels to identify icons of greater urgency. • Increase white space around label. • Use red lettering or red background. • Increase line weight of border. • Use blinking or flashing to draw attention to icon. • Increase relative size of the high urgency icon. • Always position urgent warnings within 30 degrees of the operator's normal line of sight. • Pair with an auditory cue. • Show consequence of not responding. • Do not use blue or green coloration, as those convey low urgency.
For time critical situations, such as collision avoidance, icons should be positioned so that they attract the driver's attention to the appropriate part of the vehicle or environment.


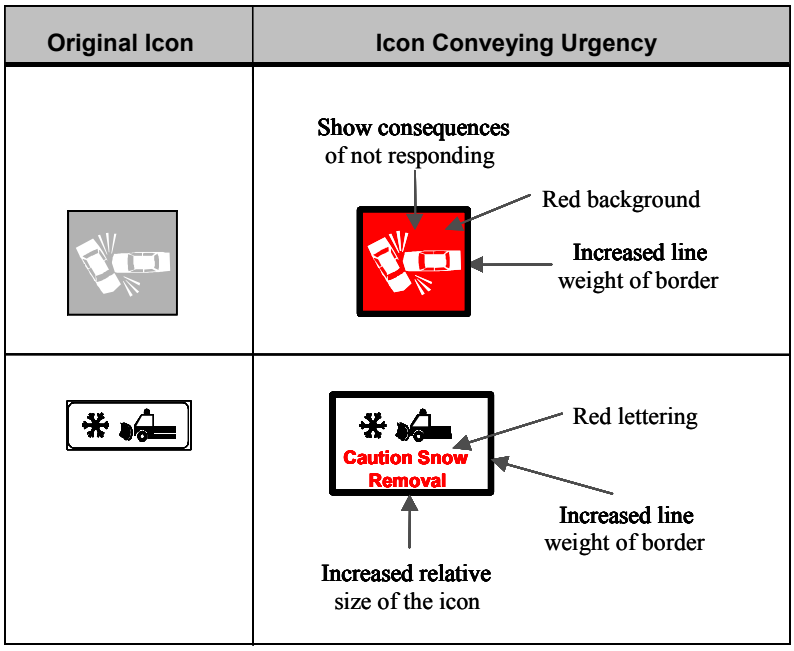


Figure 5-6. Schematic Examples of Conveying Urgency

Discussion: These guidelines enhance perceived urgency by relying on population stereotypes for the interpretation of red as suggesting danger importance. This has been shown to have a particularly strong influence on perceived urgency (reference 1). In addition, these guidelines rely on several other icon features that increase their salience, such as size, border width, and the use of flashing. These characteristics all enhance the urgency of icons individually; combining them magnifies their total effect.

Icon design features can have a strong effect on the perceived urgency of the icon. However, the perceived urgency and the driver's response to urgency depend on the context in which it is perceived. If all in-vehicle messages are designed to be perceived as highly urgent, the overall effect will be diluted. To enhance driver response to highly urgent messages requires the designer to consider the urgency of the message relative to other potential in-vehicle messages and tailor icon characteristics to the relative urgency. For example, notification of upcoming tourist attractions should not include characteristics appropriate for those of a collision avoidance warning.

Design Issues: Color appears to be a powerful mechanism to convey urgency. Text size would need to be doubled to generate the same increase in urgency that is seen when the color is changed from black to red (reference 1).

In addition, urgent symbols or icons should be located where they are most likely to be seen by the driver, thereby decreasing driver response time. According to reference 2, the area that is most easily viewed is considered to be a circular shaped or oval area roughly 10 to 15 degrees in radius around the normal line of sight (which is considered to be about 15 degrees below the horizon). The figure below indicates the optimal horizontal locations for placement of urgent symbols or icons.

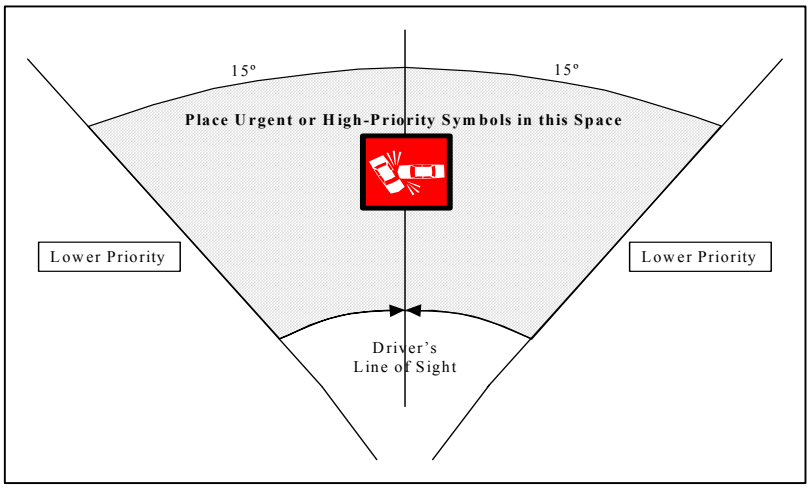


Figure 5-7. Locations of Icons Within the Visual Field (Adapted from Reference 2)

Cross References:
Flash Rate, p. 4-8; *Enhancing Icon Interpretation with Color*, p. 5-12; *Augmenting Icons with Auditory Information*, p. 6-2

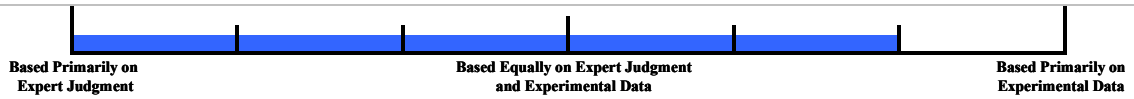
References:
1. Adams, A. S., and Edworthy, J. (1995). Quantifying and predicting the effects of basic text display variables on the perceived urgency of warning labels: Tradeoffs involving font size, border weight and color. *Ergonomics*, 38(11), 2221-2237.
2. Sanders, M. S., and McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.)*. New York: McGraw-Hill.

ENHANCING ICON INTERPRETATION WITH SHAPE

Introduction: Enhancing icon interpretation with shape refers to how the shape of an icon's outside edge or border can call attention to the hazard level being communicated and enhance drivers' interpretation of icons.

Design Guidelines

- Icons shaped like standard traffic signs convey the respective hazard level of the message.
- Use octagon-shaped icon borders for high hazard conditions or situations.
- Use diamond or inverted triangle-shaped icon borders for medium hazard conditions or situations.
- Use circle, square, or rectangular-shaped icon borders for low hazard conditions or situations.



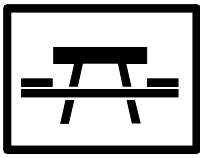
Hazard Level	Shape	Recommended Uses	Example
High	Octagon	Dangerous road conditions Vehicle equipment malfunction Road obstruction	
Medium	Diamond Inverted triangle	General road hazards Traffic congestion Construction warnings	
Low	Circle Square Rectangle	Tourist activities Food, lodging, gas Navigation instructions	

Figure 5-8. Schematic Examples of the Use of Shape in Icons

Discussion: Two warning label shape studies (references 1 and 2) presented subjects with 19 different shapes, including traffic safety sign shapes as well as other nontraditional shapes, and used a pairwise ranking procedure to determine which shapes observers rated as implying the most hazard. The studies found similar results. The inverted triangle, diamond, and octagon were perceived as the most hazardous, the circle, square, and rectangle as the least hazardous. Another study (reference 3) found analogous results with a group of industrial workers and using warning signs. Octagon and diamond shaped signs were ranked as more hazardous than circle or square signs.

Using consistent icon shapes can facilitate rapid recognition (reference 4). This takes advantage of the global superiority effect (reference 5), in which the perception of global features in a figure, such as outline shape, is more rapid than the perception of local features, such as the icon pictorial.

Design Issues: The shapes of icons connote different levels of hazard. Research has found that octagon, diamond, and inverted triangle shapes are perceived as the most hazardous, while circle, square, and rectangle shapes are perceived as the least hazardous (references 1, 2, and 3). These preferences are consistent with population stereotypes of American road signage displayed in the *Manual on Uniform Traffic Control Devices* (MUTCD). Octagon ("STOP") and diamond (warning) shaped signs require immediate action or attention. Circular ("RAILROAD CROSSING") and rectangle (regulatory) shaped signs generally are used for low priority information, such as roadside services and speed limit signs.

Cross References:
Composition of an Icon, p. 2-10; *Identifying Icons as Part of a Group*, p. 5-8; *Conveying Urgency with Icons*, p. 5-14

References:
1. Cochran, D. J., Riley, M. W., and Douglas, E. I. (1981). An investigation of shapes for warning labels. *Proceedings of the Human Factors and Ergonomics Society 25th Annual Meeting*, 395-399.
2. Riley, M. W., Cochran, D. J., and Ballard, J. L. (1982). An investigation of preferred shapes for warning labels. *Human Factors,* 24(6), 737-742.
3. Collins, B. L. (1983). Evaluation of mine-safety symbols. *Proceedings of the Human Factors and Ergonomics Society 27th Annual Meeting*, 947-949.
4. Rogers, Y. (1989). Icon design for the user interface. *International Reviews of Ergonomics, 2*, 129-154.
5. Pomerantz, J. R. (1983). Global and local precedence: Selective attention in form and motion perceptions. *Journal of Experimental Psychology: General,* 112, 516-540.

CHAPTER 6: THE AUDITORY PRESENTATION OF IN-VEHICLE INFORMATION

AUGMENTING ICONS WITH AUDITORY INFORMATION

Introduction: Augmenting icons with auditory information refers to including some type of auditory signal with an icon to make the message clearer or more salient. Almost all of the literature suggests that operator performance can be improved by combining auditory and visual messages. These channels can be used together to provide either redundant or complimentary cues to the driver.

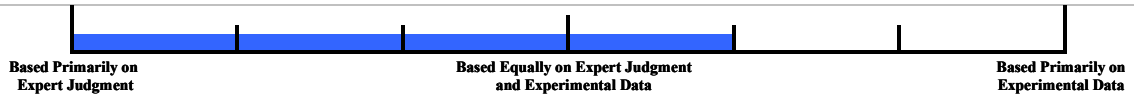
Design Guidelines
• Use the auditory modality for presenting high priority alerts and warnings; present additional contextual information visually. • Use auditory prompts when a previously static visual display changes. • Use auditory prompts when high priority information is automatically displayed. • Use a combination of visual and auditory prompts to repeating low complexity messages.


Table 6-1. Heuristics for Assessing Priority

Priority is a function of the urgency of a response and the consequences of failing to make a response.

High Priority	Low Priority
Fast response needed (0–5 minutes)	No response needed (5 min +)
Serious consequences (death or injury)	No immediate consequences
Examples: Notification of serious traffic conditions that may affect the safety of the driver or mechanical problems that could impact the safety of the driver or the condition of the vehicle	Examples: Vehicle maintenance schedules, or weather information

Complexity is a function of how much information is being provided and how difficult it is to process. The phrase "information units" is used to describe the amount of information presented in terms of key nouns and adjectives contained within a message. The design guideline entitled "Design of Speech Messages" on page 6-14 provides a tool for determining the number of information units.

Table 6-2. Heuristics for Assessing Complexity

High Complexity	Low Complexity
>9 information units	3–5 information units
Processing time >5 s	Processing time <5 s
Examples: Transit schedules in area along route or routing restrictions for specific vehicle cargos	Examples: Directions of turns or estimates of travel costs

Discussion: It is widely believed that combining an auditory and visual presentation of information could improve operator performance. Reference 1 recommends that the auditory modality be used as: (1) an auditory prompt to look at a visual display, or (2) supplemental information for a visual display. Providing information in this redundant fashion will lessen the need for a driver to scan the visual display and allow him or her to review the information if it is not fully understood or remembered. Reference 2 emphasizes the importance of redundant coding by stating that presenting information in the auditory and visual modalities will accommodate transient shifts in noise within the processing environment (e.g., visual glare, background noise, verbal distractions), which may influence one format or another. Display format redundancy also accommodates the strengths and abilities of different population groups (e.g., high spatial ability vs. high verbal ability).

Design Issues: Reference 3 suggests that, to determine the most appropriate display modality for presenting a particular information element, it is extremely important to predict whether the driver will need the information predrive or in-transit. Then, based upon other issues such as the complexity and urgency of the information, a decision can be made regarding which modality will accomplish the goal with the least amount of compromise to driver safety.

In reference 4, a driving simulator was used to study the benefits of multimodal displays (both auditory and visual). The multimodal displays were associated with better driving performance than auditory-only or visual-only displays, as well as better performance on a navigation task. Both the multimodal and auditory-only displays were associated with better emergency responses than the visual-only display.

Cross References:
Conveying Urgency with Icons, p. 5-14; *Determining the Appropriate Auditory Signal*, p. 6-4; *Design of Speech Messages*, 6-14

References:

1. Dingus, T. A., and Hulse, M.C. (1993). Some human factors design issues and recommendations for automobile navigation information systems. *Transportation Research*, 1C(2), 119-131.
2. Wickens, C. D. (1987). Information processing, decision-making, and cognition. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Mollenhauer, M. A., Dingus, T. A., and Hulse, M. C. (1995). Recommendations for sensory mode selection for ATIS displays. *Proceedings of the Institute of Transportation Engineers 65th Annual Meeting: A Compendium of Technical Papers,* 667-672.
4. Liu, Y., and Dingus, T. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Human factors evaluation of the effectiveness of multi-modality displays in advanced traveler information systems* (FHWA-RD-150). Washington, DC: Federal Highway Administration.

DETERMINING THE APPROPRIATE AUDITORY SIGNAL

Introduction: To determine the appropriate auditory signal means to choose the type of signal (simple tone, earcon, auditory icon, or speech message) that will best augment the visual message presented to the driver. The following auditory signals represent the most frequently used options:

Simple tones: Single or grouped frequencies presented simultaneously.
Earcons: Musical tones that can be used in structured combinations to create auditory messages (reference 1). These are sometimes referred to as complex tones.
Auditory icons: Familiar environmental sounds that intuitively convey information about the object or action they represent (reference 2). These are sometimes referred to as naturalistic sounds or earcons, and are intuitively recognizable.
Speech messages: Voice messages that add information beyond pure sound.

Design Guidelines

- Use simple tones and auditory icons when an immediate response is required.
- Earcons should be used when it is important for the driver to know that pieces of information are related.
- Auditory icons are effective for use in collision-warning applications (i.e., horn or skidding tires).
- Use speech messages when a high degree of message flexibility is required.
- Use speech messages when a high degree of message detail is required.
- Use speech messages when the meaning of tones or other sounds may be forgotten under stress.
- Use speech messages when the auditory message deals with a future point in time for which there must be some preparation (i.e., time or distance to turn).
- Speech message displays should not be used for time-critical tasks.

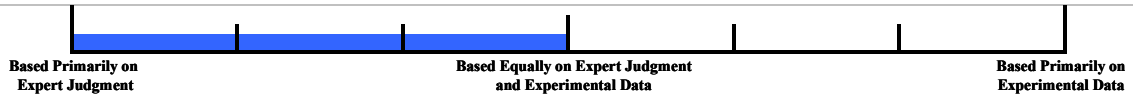


Table 6-3. Ratings of Audio Signals for Various Functions

Functions	Example Message	Simple Tones	Earcons	Auditory Icons	Speech Messages
Status indication	Navigation system on and functioning	Good	Good	Fair	Poor
Alerting (attentional)	Generic warning indicator (to divert attention to a display)	Good	Fair	Poor	Poor
Warning (informational)	Rear-end collision-avoidance warning indicator	Fair	Poor	Good	Fair
Presentation of qualitative information	Location of next available lodging	Poor	Poor	Poor	Good
Presentation of quantitative information	Cost of upcoming toll bridge	Poor	Poor	Poor-Fair	Good

Discussion: According to reference 3, there are a limited number of tones (five to six) that are absolutely recognizable; therefore, they are not a good choice for presenting quantitative information. Also, unless they are presented in close temporal sequence, it is difficult to make qualitative judgments regarding deviations. They are good, however, for gaining the attention of the driver, whether it be simply for the purpose of getting him or her to attend to information being presented or to warn of an impending danger. Like tones, earcons are also limited because it is difficult to make qualitative judgments regarding deviations from a desired state or value. It is also difficult to obtain accurate quantitative information for earcons. Earcons are most effective when presenting a family of related sounds (see reference 4). One powerful feature associated with the use of earcons is that "related information can be given related sounds and hierarchies of information can be represented" (reference 5). They are extremely flexible. However, their meaning is not apparent and must be learned. Therefore, they are not a good choice for presenting critical, time-dependent information to the driver. Auditory icons are most effective when they can be mapped to everyday, naturally occurring sounds (see reference 2). When this is the case, they are extremely easy for the user to both learn and remember. They have been shown to be successful in collision warning applications (see references 6 and 7) in reducing reaction times to collision events. The problem with auditory icons, however, is that not all information items to be presented in IVIS systems can be mapped to a naturally occurring sound. In these instances, the designer has to create metaphors for the icons, which can end up being just as abstract as a pure tone or earcon. Speech messages are most effective for rapid, but not automatic, communication of complex, multidimensional information; the meaning of the message is intrinsic in the signal and context, and minimum learning is required. However, speech messages can be inefficient, more easily masked, and have problems associated with repeatability and confusions with other sounds in the automobile such as conversations and noise from the radio.

Design Issues: Some advantages and disadvantages associated with the use of each of the methods for presenting auditory information are given above. This is by no means an exhaustive literature review associated with the use of the auditory modality, but a tool for aiming the designer in the most appropriate direction. It should also be mentioned that the auditory signals discussed are being presented as a method for augmenting visual messages or to act as a redundant cue, not as a sole means for presenting in-vehicle information to the driver.

Cross References:
Chapter 6: The Auditory Presentation of In-Vehicle Information

References:

1. Brewster, S. A., Wright, P. C., and Edwards, A. D. (1993). An evaluation of earcons for use in auditory human-computer interfaces. *INTERCHI '93*, 222-27.
2. Gaver, W. W. (1986). Auditory icons: Using sound in computer interfaces. *Human-Computer Interaction*, 2(2), 167-177.
3. Advanced Systems Technology Branch. (1993). *Preliminary human factors design standards for airway facilities* (ACD-350). Atlantic City International Airport, NJ: Federal Aviation Administration Technical Center.
4. Blattner, M. M., Sumikawa, D. A., and Greenberg, R. M. (1989). Earcons and icons: Their structure and common design principles. *Human-Computer Interaction*, 4, 11-44.
5. Brewster, S. A., Wright, P. C., and Edwards, A. D. N. (1994). A detailed investigation into the effectiveness of earcons. In G. Kramer (Ed.), *Auditory display: Sonification, audification, and auditory interfaces, Volume XVII*. Reading, MA: Addison Wesley.
6. Graham, R., Hirst, S. J., and Carter, C. (1995). Auditory icons for collision avoidance warnings. *Proceedings of the ITS America 1995 Annual Meeting*, 1057-1063.
7. Belz, S. M., Robinson, G. S., and Casali, J. G. (1998). Auditory icons as impending collision system warning signals in commercial motor vehicles. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting*, 1127-1131.

DESIGN OF SIMPLE TONES

Introduction: Simple tones are auditory signals that convey information through the use of single or grouped frequencies presented simultaneously. For the purposes of this guideline document, simple tones are discussed as a means for augmenting the visual presentation of in-vehicle messages and are not meant to be used as the only means for presenting in-vehicle messages.

Design Guidelines

- Appropriate loudness levels are 15-25 decibels (dB) above the predicted masked threshold.
- Auditory warning signals should be less than 30 dB above the masked threshold to minimize operator annoyance and the disruption of communication.
- The pitch of warning sounds should be between 150 and 1000 Hertz (Hz).
- Continuous tones should be avoided because they are usually high pitched and aversive, prevent communication if they are loud, and are easy to habituate because they never change.

When more than one tone is used:

- Avoid tones with the same on/off ratio.
- Avoid tones that share the same temporal pattern.
- Avoid tones that begin in the same way (i.e., with a long tone).
- No more than 6 simple tones should be used.

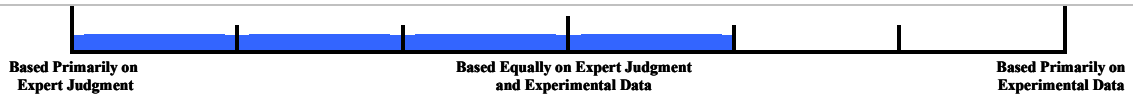


Table 6-4. Advantages and Disadvantages Associated with the Use of Simple Tones

Advantages of Simple Tones	Disadvantages of Simple Tones
• Can serve an alerting function. • Can increase detectability of messages. • Can produce faster reaction times. • Useful in situations where the noise environment is too complex for adequate voice warnings.	• Difficult to establish appropriate loudness levels, especially in the constantly changing in-vehicle environment. • Can be confusing because: (1) Their meaning is not inherent. (2) There may be too many to remember. • Number of tones that can be reliably discriminated is low. • Can induce startle responses. • Difficult to prioritize or determine perceived urgency.

Discussion: Simple tones are similar to arbitrary symbols and only become meaningful through learning. Their main function is to alert the driver to a situation or event. The event could be an impending collision, or it could be simply a display of additional information via text, voice messages, or even in-dash indicators. There are many instances for which a simple tone may be appropriate; however, it is important to limit their use to no more than six per display (reference 1).

Design Issues: One of the central problems associated with a simple auditory tone is loudness. In the vehicle, the noise level is constantly changing; the driver may be speeding down the interstate with the windows down, chatting with a passenger, listening to the radio, or sitting quietly at a stoplight. In each of these situations, the appropriate level for presenting auditory information varies. Warnings that are too loud can: (1) be shut off; (2) cause the driver to be attending to the warning when he/she should be attending to the situation it is warning of; (3) distract from the main task; or (4) startle the driver, causing an inappropriate response. However, warnings that are not loud enough are likely to be missed. Therefore, determining the appropriate auditory threshold is extremely important. See references 2 and 3 for guidelines regarding the range for predicting thresholds and constructing auditory warning systems.

Cross References:
Determining the Appropriate Auditory Signal, p. 6-4

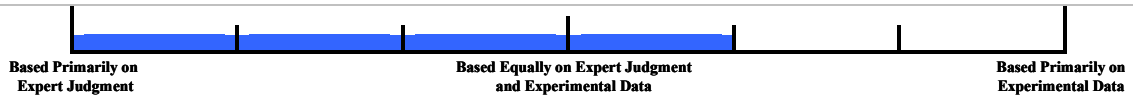
References:
1. Advanced Systems Technology Branch. (1993). *Preliminary human factors design standards for airway facilities* (ACD-350). Atlantic City International Airport, NJ: Federal Aviation Administration Technical Center.
2. Patterson, R. D. (1982). *Guidelines for auditory warnings systems on civil aircraft* (Civil Aviation Authority paper 82017). London: Civil Aviation Authority.
3. Zwicker, E., and Scharf, B. (1965). A model of loudness summation. *Psychological Review*, 72, 3-26.

DESIGN OF COMPLEX TONES

Introduction: Complex tones are auditory signals that present information through the use of a hierarchical nesting of pulses and bursts that combine to form the signal or sound. The parameters of complex tones can have an important effect on perceived urgency, annoyance, and appropriateness.

Design Guidelines

- The amplitude envelope of the initial pulse should include a 20 millisecond (ms) onset to reduce startle effects.
- The pulse should be composed of multiple frequency components, such as formants or harmonics, to mitigate masking due to background noise.
- The temporal pattern of auditory signals should be as distinct as possible, otherwise confusion is likely, even if the spectral content is substantially different.



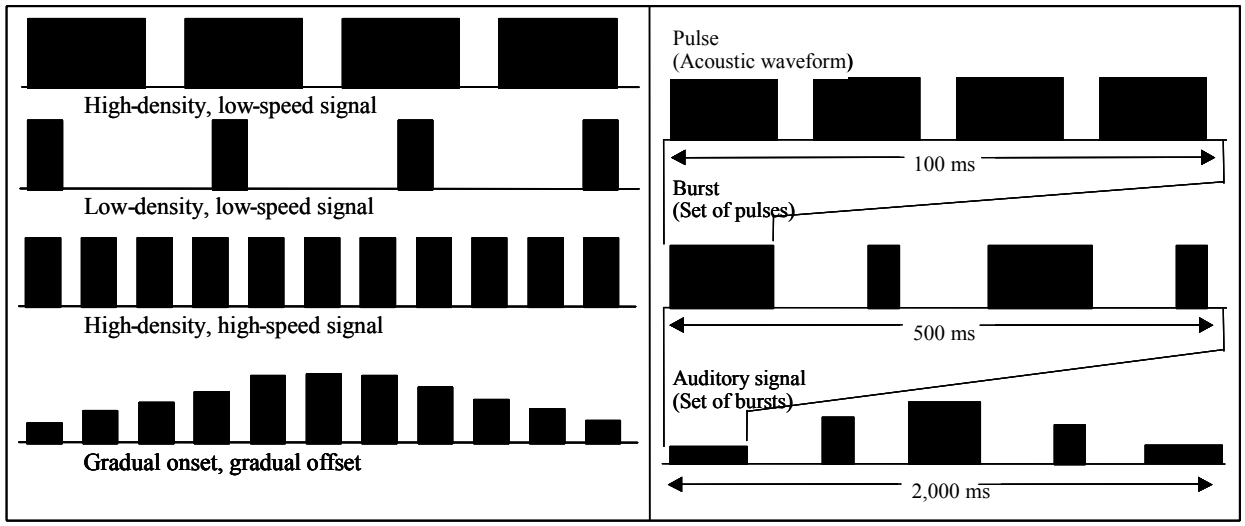


Figure 6-1. Temporal Parameters of Auditory Signals—Pulse, Burst, and Sound Parameters Defined Graphically

Temporal parameters of the pulse, burst, and sound:

Duration:	The time from the beginning to the end of a pulse or burst.
Inter-pulse interval:	The time between the end of one pulse or burst and the beginning of the next.
Inter-burst interval:	The time between the end of one pulse or burst and the beginning of the next.
Speed:	The time between the beginning of a pulse or burst to start of the next.
Density:	Pulse or burst duration divided by pulse speed.
Onset time:	The time from the start of the pulse or burst until it reaches maximum output.
Offset time:	The time in which the pulse or burst falls from maximum output to zero.
Duty cycle:	Number of pulses per second.

Discussion: Pulses combine to form bursts and bursts combine to form the overall auditory signal. Pulses, bursts, and the sound all have temporal sound parameters that affect confusion, urgency, and annoyance. This hierarchy of sound parameters is defined by the timescale, where the timescale of the pulse is from 100 to 300 ms and the timescale of the burst is 500 to 2,000 ms. The complete warning signal ranges from 2,500 ms to tens of seconds.

The harmonic content that defines the timbre or formant also has a powerful effect on the perception of the alert (reference 1). A signal composed of a harmonic frequency series is substantially less urgent than one composed of a random or partially random frequency series (reference 1). The formant determines the characteristic quality of vowel sounds and is composed of several frequency regions of relatively great intensity. More specifically, a formant is a resonant peak in the frequency spectrum of a voice and is a critical acoustic feature of most speech sounds. Formants are different than more common combinations of frequency components, such as harmonic series. Rather than being equally spaced across the frequency spectrum, formants are distributed in an apparently random distribution. The critical attribute of a formant is that it determines the characteristic quality of vowel sounds produced by humans. Formants reflect anatomical properties of the vocal tract and are fundamental characteristics of natural speech sounds and seem more likely to influence emotional content of a sound compared to artificial frequency combinations, such as octaves. Research has shown that formants affect the perception of sound characteristics related to urgency and annoyance (reference 2).

Design Issues:
The parameters that affect perception at the level of the sound may not have the same effect at the level of the burst. For example, pulse onset has a different effect than the onset of the entire signal. A slow onset at the level of the pulse increases urgency, whereas longer onsets at the burst or signal level decrease urgency. This result suggests that empirical findings regarding the effect of temporal parameters on pulse perception may not generalize to burst perception.

Cross References:
The Auditory Presentation of In-Vehicle Information, p. 6-1; *Perceived Urgency of Auditory Signals*, p. 6-16; *Perceived Annoyance of Auditory Signals*, p. 6-22

References:
1. Edworthy, J., and Adams, A. (1996). *Warning design: A research perspective*. Bristol, PA: Taylor and Francis.
2. Stanford, L. M., McIntyer, J. W. R., Nelson, T. M., and Hogan, J. T. (1988). Affective responses to commercial and experimental auditory alarm signals for anesthesia delivery and physiological monitoring equipment. *International Journal of Clinical Monitoring and Computing,* 5, 111-118.

DESIGN OF EARCONS

Introduction: Earcons refer to auditory signals that present information through abstract musical tones that can be used in structured combinations to create auditory messages (reference 1). Earcons are also sometimes referred to in the literature as complex tones. Earcons have five parameters that can be modified to create different messages: rhythm, pitch, timbre, register, and dynamics.

Rhythm: Whole note, dotted half note, half note, quarter note, dotted eighth note, eighth note, sixteenth note.
Pitch: Eight octaves of 12 pitches each.
Timbre: Sinusoidal, sawtooth, triangular, rectangular.
Register: Low, medium, high.
Dynamics: Soft, medium, loud, soft to loud, loud to soft.

A motive, the building block of an earcon, is defined as "a rhythmicized sequence of pitches. Rhythm and pitch are the fixed parameters of a motive, while timbre, register, and dynamics are the variable parameters of motives" (reference 2).

Design Guidelines

- Use synthesized musical timbres that are subjectively easy to tell apart (i.e., organ and brass).
- Do not use pitch alone to distinguish between tones unless there are very significant differences. Some suggested ranges for pitch are max: 5 kHz and min: 125 Hz–150 Hz.
- Use tones that are three or more octaves apart.
- Make the rhythm as different as possible. Putting a different number of notes in each rhythm is effective.
- Some suggested ranges for intensity are max: 20 dB above threshold and min: 10 dB above threshold.
- When playing combinations of multiple earcons, a gap of 0.1 second should be between them so that the user can tell where one finishes and another starts.

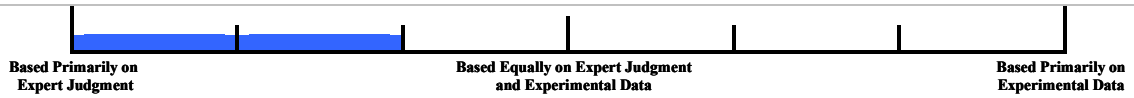


Table 6-5. Three Methods for Constructing Earcons (from Reference 3)

Method	Description	Example
Combining	The process of combining to create an earcon means linking different motives together in a chain-like sequence. Let *A* and *B* be earcons that represent different messages. *A* and *B* can be combined by linking *A* and *B* to form a third earcon *AB*.	A = urgent B = e-mail AB = urgent e-mail
Transforming	The process of transformation cosmetically alters a motive by changing its timbre, register, and/or tempo. However, it is important not to alter the motive beyond recognition. The semantic implications are a change of state in an object, not a change of object. Earcon *A* may be transformed into earcon *B* by modification in the construction of *A*.	A = system up A' or B = system down
Inheriting	The process of inheriting is one in which a single earcon is heard in an increasingly complex chain. Imagine a tree of earcons with a family motive at the root. The next level adds pitch to the rhythm of the family motive. At the next level, a recognizable timbre is added.	A = the family motive (i.e., in-vehicle messaging) A + pitch = AB (i.e., message received) AB + timbre = ABC (i.e., message forwarded)

Discussion: Earcons are said to be a powerful and flexible means for creating auditory messages (see references 2, 3, 4, and 5). Reference 3 argues that the advantages associated with the use of earcons are clear: (1) they are easily constructed on any workstation or personal computer; (2) the sounds do not have to correspond to the objects they represent, so objects that either make no sound or that make an unpleasant sound can be represented; and (3) studies have shown that they are preferred over other types of auditory communication (see reference 6). The main disadvantage, however, is that, like simple tones, earcons must be learned. Their meaning is not inherent in the signal.

Design Issues: Reference 4 presents extensive, very specific guidelines for developing earcons, examining such issues as the psychoacoustical characteristics of sound, the formal arrangement of sounds into earcons, and the meaning and interpretation of earcons. Reference 5 presents slightly more general information. However, the concepts discussed require some knowledge of the parameters associated with sound. References 4 and 5 argue that experts, such as professional composers, should be included on any design team that is attempting to construct earcons. "The science of sound is a highly technical, diverse, and complicated discipline. Only an expert in this field understands the existence, importance, implications, and consequences of and the means of dealing with, the many perceptual problems and intricacies of sound" (reference 2).

For the purposes of this guideline document, earcons are discussed as a means of augmenting the visual presentation of in-vehicle messages and are not meant to be used as the only way to present in-vehicle messages.

Cross References:
Determining the Appropriate Auditory Signal, p. 6-4; *Perceived Urgency of Auditory Signals*, p. 6-16

References:

1. Brewster, S. A., Wright, P. C., and Edwards, A. D. (1993). An evaluation of earcons for use in auditory human-computer interfaces. *INTERCHI '93*, 222-227.
2. Blattner, M. M., Sumikawa, D. A., and Greenberg, R. M. (1989). Earcons and icons: Their structure and common design principles. *Human-Computer Interaction,* 4, 11-44.
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5. Sumikawa, D. A., Blattner, M. M., Joy, K. I., and Greenberg, R. M. (1986). *Guidelines for the syntactic design of audio cues in computer interfaces* (UCRL-92925-REV.1). Livermore, CA: Lawrence Livermore National Laboratory.
6. Jones, S. D., and Furner, S. M. (1989). The construction of audio icons and information cues for human computer dialogues. *Contemporary Ergonomics 1989. Proceedings of the Ergonomics Society's 1989 Annual Conference,* 436-441.

DESIGN OF AUDITORY ICONS

Introduction: Auditory icons are familiar environmental sounds that intuitively convey information about the object or action that they represent (reference 1). They are sometimes also referred to in the literature as naturalistic sounds or earcons. The three types of auditory icon are iconic, metaphorical, and symbolic.

- Iconic auditory icons sound like the object or action they represent (e.g., the sound of a crash to indicate a collision warning).
- Metaphorical auditory icons sound like some element of the object or action they represent (e.g., the sound of children to indicate a school crossing).
- Symbolic auditory icons rely on social convention for meaning (e.g., the sound of a siren to indicate an ambulance approaching).

The figure below (from reference 2) demonstrates some of the performance improvements that might be obtained when using an auditory icon for a warning component.

Design Guidelines

- By definition, auditory icons must be identifiable as having relevance or conveying some inherent meaning (see above for examples of iconic, metaphorical, and symbolic auditory icons).
- Auditory icons should be detectable 10 to 20 dB above the masked threshold.
- No more than six auditory icons should be used in an auditory icon set.
- Auditory icons should strive to attract the attention of the driver without generating a startle reaction. Special attention should be paid to the perceived urgency associated with different candidate auditory icons.

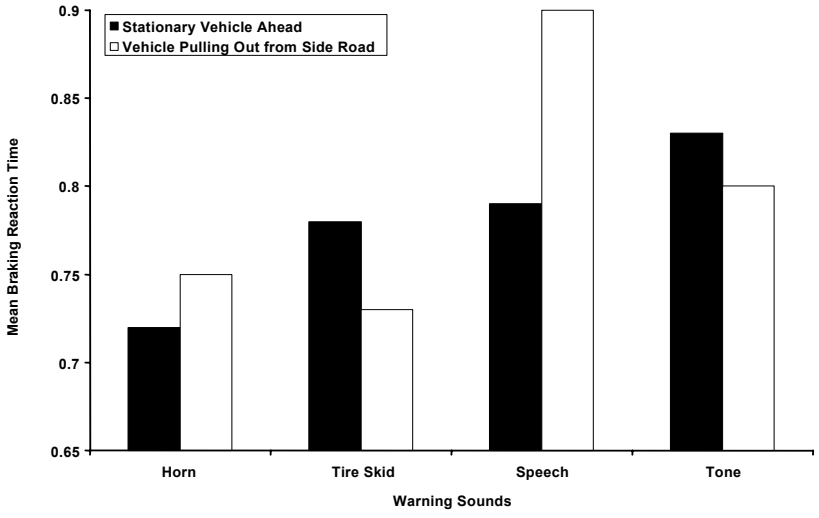

Figure 6-2. Brake Reaction Times for Different Warning Sounds (from Reference 2)

Discussion: The goal of auditory icon design is to map the attributes of a computer event to some everyday sound-producing event (see references 1 and 3). This makes auditory icons extremely easy for users to learn and remember, as their meaning is inherent. Perhaps this is why they have been examined for use in collision warning applications. One could argue that drivers' responses would be based on experiences in which they have heard these sound occur naturally, thus their responses will be faster. This has, in fact, been shown to be the case. Reference 2 describes a study in which drivers were required to carry out a tracking task while at the same time attending to a road scene interspersed with imminent collisions. They were asked to respond to each collision warning they were given and determine the appropriate braking response. Four collision warnings were tested (a simple tone; a speech warning "ahead"; the sound of a car horn; and the sound of skidding tires). Results of the study showed that braking reaction times were faster for the auditory icons than for the more traditional warning sounds. Another study described in reference 4, found similar results. Braking reaction times for collision warnings using auditory icons were shown to be significantly less than for conventional collision warnings (tones).

Design Issues: While the experiments described above show an improved braking reaction time associated with the use of auditory icons in collision warning applications, the icons are not necessarily the best choice for presenting this type of information. In addition to producing faster braking reaction times, they also produced a higher number of inappropriate reactions due to startle effects (e.g., slamming on brakes for a low-level warning; see reference 2). This type of reaction could actually negate any benefits of having a collision warning system and potentially put the driver's safety at risk. Ensuring that the appropriate level of urgency is projected to the driver is a very important design issue. References 5 and 6 suggest that factors such as the frequency, amplitude, envelope shape, and melodic structure of a warnings can all affect perceived urgency. Thus, altering certain sound parameters may allow a designer to reduce the startling affect of these type of warnings.

For the purposes of this guideline document, auditory icons are discussed as a means for augmenting the visual presentation of in-vehicle messages and are not meant to be used as a sole means for presenting in-vehicle messages.

Cross References:
Determining the Appropriate Auditory Signal, p. 6-4; *Perceived Urgency of Auditory Signals*, p. 6-16

References:

1. Gaver, W. W. (1986). Auditory icons: Using sound in computer interfaces. *Human-Computer Interaction*, 2(2), 167-177.
2. Graham, R., Hirst, S. J., and Carter, C. (1995). Auditory icons for collision avoidance warnings. *Proceedings of the ITS America 1995 Annual Meeting,* 1057-1063.
3. Gaver, W. W. (1989). The sonic finder: An interface that uses auditory icons. *Human-Computer Interaction*, 4(1), 67-94.
4. Belz, S. M., Robinson, G. S., and Casali, J. G. (1998). Auditory icons as impending collision system warning signals in commercial motor vehicles. *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting,* 1127-1131.
5. Edworthy, J., Loxley, S., and Dennis, I. (1991). Improving auditory warning design: Relationship between warning sound parameters and perceived urgency. *Human Factors*, 33(2), 205-231.
6. Hellier, E. J., Edworthy, J., and Dennis, I. (1993). Improving auditory warning design: Quantifying and predicting the effects of different warning parameters on perceived urgency. *Human Factors*, 35(4), 693-706.

DESIGN OF SPEECH MESSAGES

Introduction: Speech messages refer to auditory signals that present information through voice messages that add information beyond pure sound. For the purposes of this guideline document, speech is discussed as a means for augmenting the visual presentation of in-vehicle messages and is not meant to be used as the only means of presenting in-vehicle messages.

Design Guidelines

- If speech must be used in a time-critical application (i.e., warning), the message should be kept to a single word or a short phrase with the fewest number of syllables possible.
- Messages that are not urgent or for which a response may be delayed can be a maximum of seven units of information in the fewest number of words possible. If the information cannot be presented in a short sentence, the most important information should be presented at the beginning and/or the end of the message.
- Navigation instructions should be limited to three or four information units (i.e., "Accident ahead, merge right" or "Turn right in ½ mile").
- Do not try to make the voice sound too human. A machine should have a machine voice to cue its identity when it speaks.
- Provide a means for repeating speech messages.
- Provide a redundant visual presentation of the information being presented aurally.

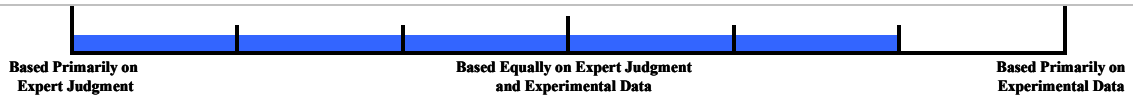

Table 6-6. Determining the Number of Information Units

Message Type	Number of Information Units	Example Message
Urgent message (i.e., collision warning)	1 unit	Brake
Navigation instructions	3–4 units	Road Construction Ahead at Jaspertown
Non-urgent message (i.e., motorist services)	7 units	Gas Station Ahead Exit #46 Turn Right

Table 6-7. Examples of Auditory Messages

Suggested	Not Suggested
"Oil change needed by July 1, 2003."	"Vehicle maintenance log shows that vehicle oil change is due and should be completed by July 1, 2003."
"Turn right in ½ mile."	"At the next stoplight, turn right onto Stark Lane in ½ mile."

Discussion: Speech displays are an effective means for communicating information to the driver. In addition to warning, they can be used to provide responses to user queries and feedback from control inputs. Warnings, however, have received the majority of attention in speech display research. They are effective in that they not only alert the driver to an emergency situation, but they also provide additional information about the nature of the problem (reference 1). However, the added length of the message can increase the driver's response time. Therefore, an important tradeoff exists between comprehension and clarity (i.e., message length) and driver response times. The guidelines given on the previous page should aid designers in making this tradeoff.

Design Issues: When presenting messages that do not require immediate action, reference 2 suggests several options exist for helping the driver use the information: (1) present the information in the order of importance or relevance to the driver; (2) present the most important information at either the beginning or the end of the message because it is easiest to recall; (3) highlight the most important parts of the message; (4) provide a means for repeating the message—this is especially helpful for older drivers; and (5) provide a redundant visual presentation of the information—this is also helpful for older drivers.

One important design decision is whether to include an alerting tone before presenting a voice message. References 3, 4, and 5 found that voice warnings preceded by an alerting tone did not produce faster response times than the voice warning by itself. However, in one study, an alerting tone actually increased response time (see reference 3). Reference 6 supports the notion that synthesized speech is distinctive from human speech and can perform an alerting function in addition to transferring the pertinent information to the driver. This is another reason for making sure that we do not try to make the speech warnings sound too human. A machine-like voice will better cue the driver to its identity.

Another important consideration when determining whether to use speech displays is driver acceptance. Existing research indicates that speech displays should be used sparingly because the auditory channel can quickly become cluttered or overloaded with stimuli (references 7, 8, and 9). Speech displays are inherently intrusive and have a tendency to annoy the user if they are presented too frequently. In fact, speech displays used in certain aircraft applications have even been disabled so that the pilots would not have to listen to the chatter of redundant or irrelevant messages. Because of the potential problems of acceptance, speech displays should only be used when the visual modality is overloaded, and they should always be accompanied by a visual representation so that the information can be referred to again at a later time (reference 9).

Cross References:
Determining the Appropriate Auditory Signal, p. 6-4

References:
1. Wogalter, M. S., and Young, S. L. (1991). Behavioural compliance to voice and print warnings. *Ergonomics*, 34(1), 78-89.
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6. Cowley, C. K., and Jones, D. M. (1992). Synthesized on digitized? A guide to the use of computer speech. *Applied Ergonomics*, 23(3), 172-176.
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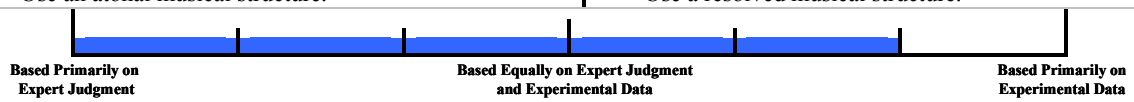
PERCEIVED URGENCY OF AUDITORY SIGNALS

Introduction: Perceived urgency of auditory signals refers to the subjective impression of urgency that a signal gives to the person hearing it. The goal is to match the urgency of the auditory signal to the urgency of the situation to which it pertains. This is called "urgency mapping." Reference 1 has shown that the perceived urgency of an auditory signal can be directly manipulated by changing certain temporal or melodic parameters, such as speed, rhythm, number of units, speed change, fundamental frequency, pitch range, pitch contour, and musical structure.

Temporal Parameters	*Melodic Parameters*
Speed (slow = 1.5 pulse/sec; fast = 6 pulse/sec)	Fundamental frequency (low = 200 Hz; high = 800 Hz)
Rhythm (regular = all pulses equally spaced; irregular = pulses not equally spaced)	Pitch range (small = 3 semitones; large = 9 semitones)
Number of units (1 = 1-4 pulse burst; 4 = 4-4 pulse bursts)	Pitch contour (down/up; random)
Speed change (slowing down; speeding up)	Musical structure (resolved = from natural scales; atonal = random sequence of pulses)

Design Guidelines

To increase the perceived urgency:	**To decrease the perceived urgency:**
• Use faster auditory signals.	• Use slower auditory signals.
• Use regular rhythms.	• Use irregular rhythms.
• Use a greater number of units (4).	• Use fewer number of units (1).
• Use auditory signals that speed up.	• Use auditory signals that slow down.
• Use high fundamental frequencies.	• Use low fundamental frequencies.
• Use a large pitch range.	• Use a small pitch range.
• Use a random pitch contour.	• Use a down or up pitch contour.
• Use an atonal musical structure.	• Use a resolved musical structure.



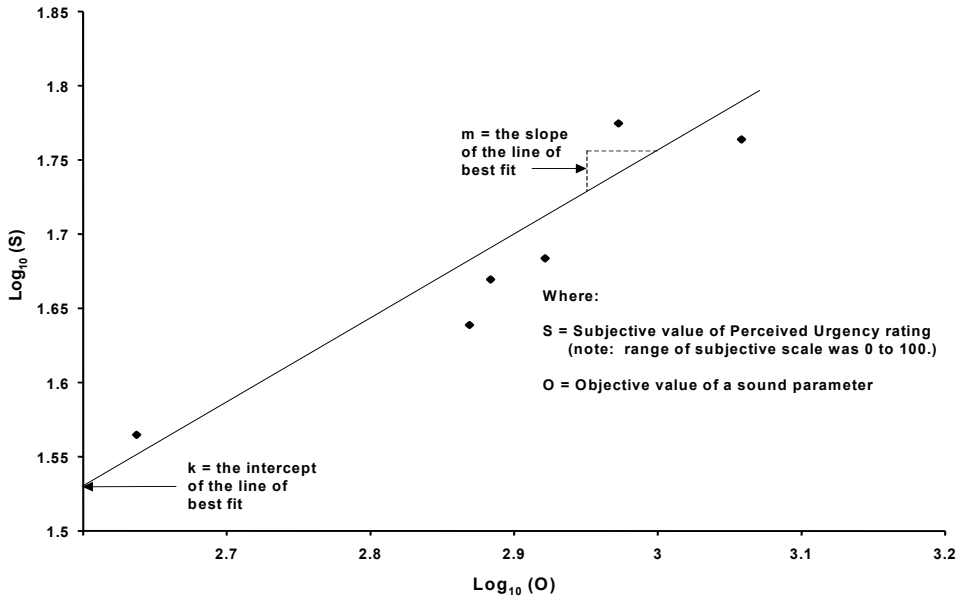


Figure 6-3. Example of Using Steven's Power Law for Producing Urgency Exponents (see references 2 and 3 for more detailed explanations and examples)

$$S = kO^m \quad (8)$$

Discussion: The perceived urgency of auditory signals has been researched to some extent in the past 10 years. The results have shown that varying certain acoustical parameters has a strong and consistent effect on a person's subjective impression of the urgency of the warning. Reference 1 provides designers with a database concerning the subjective ratings and rankings of the perceived urgency of many of the temporal and melodic parameters. Designers can use this information to produce warnings with the appropriate levels of perceived urgency. This is extremely important, as new research has discovered that increases in the perceived urgency of a warning correlates with faster reaction times (see references 4 and 5). Therefore, if auditory signals are designed with urgency mapping in mind, more effective warnings can be developed.

Design Issues: References 2 and 3 show how, using Steven's power law, certain quantifiable sound parameters such as speed, number of repetitions, and frequency can be scaled and compared directly. In reference 3, urgency exponents for speed, number of repetitions, and frequency were calculated to be 1.35, 0.5, and 0.38, respectively. Because speed has a higher urgency exponent, it means that the subjective assessment of urgency changes faster as the change in speed increases. Reference 6 states that these results imply that a small change in the speed of a warning increases its urgency considerably, whereas a much larger change in the number of repetitions would be required to produce the same change. The ability to quantify this subjective assessment allows designers of IVIS to develop a set of auditory signals that would sound different but, through a manipulation of certain parameters, would have the same urgency.

Reference 7 suggests that urgency mapping tests be carried out on sets of auditory signals being used as alarms, especially if they are abstract alarm sounds. The first step in this process is to get a group of people who have a good working knowledge of the environments in which the alarms will be used to rate the situational urgency of the referents on a scale from 1 to 5. The second step is to have a different group of people rate on a scale from 1 to 5 the psychoacoustical urgency of the auditory warnings, without any knowledge of the referents. The next step is to correlate the two measures. If there is a significant correlation, then the designer may decide to make little or no changes to the alarm. However, if there is no correlation or a negative correlation, then the designer should modify the alarm. The list on the previous page may help a designer choose which parameters to alter and how to alter them to make an alarm more or less urgent.

Cross References:
Design of Earcons, p. 6-10; *Design of Auditory Icons*, p. 6-12

References:
1. Edworthy, J., Loxley, S., Geelhoed, E., and Dennis, I. (1989). The perceived urgency of auditory warnings. *Proceedings of the Institute of Acoustics*, 11(5), 73-80.
2. Hellier, E. and Edworthy, J. (1989). Quantifying the perceived urgency of auditory warnings. *Canadian Acoustics,* 17(4), 3-11.
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4. Haas, E. C. and Casali, J. G. (1995). Perceived urgency and response time to multi-tone and frequency modulated warning signals in broadband noise. *Ergonomics*, 38(11), 2313-2326.
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GENERAL DESIGN GUIDELINES FOR AUTOMATIC SPEECH RECOGNITION SYSTEMS

Introduction: Automatic Speech Recognition (ASR) devices recognize human speech and, in an in-vehicle context, treat speech commands as inputs to an IVIS device. Currently, ASR is viewed as an enabling technology in intelligent transportation system (ITS) development. Many of the state-of-the-art advances associated with ITS involve complex in-vehicle devices that include a host of functions including: navigation, e-mail, motorist services, internet access, cellular phone capabilities, "infotainment," and fax. Such broad functionality is associated with greater perceptual, information processing, and psychomotor demands on the driver, and presents a crucial challenge to IVIS developers. ASR is viewed as a means to allow the driver to interact with the IVIS device, while maintaining his/her eyes on the road and hands on the wheel. Moreover, recent advances in ASR techniques (speaker independent devices, increased vocabulary size, reduced processing time, noise-filtering and word-matching algorithms) suggest that it may be an attractive alternative to traditional approaches to the driver-vehicle interface (DVI).

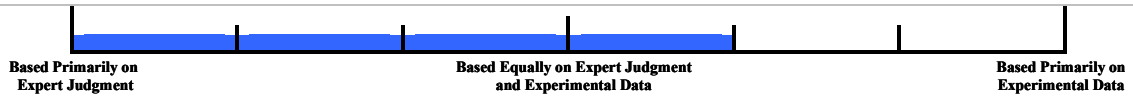
Design Guidelines
• For IVIS applications, ASR devices should be used to aid complex tasks that involve high visual, cognitive, or manual requirements. • Vocabulary sets for ASR devices should: reflect natural language conventions as much as possible, avoid similar-sounding words or phrases, and be small enough so that drivers can recall command words rapidly and with few or no errors. • The microphone for an ASR device should be located on the forward portion of the vehicle headliner, right in front of the driver (reference 3). • Drivers should be provided with immediate feedback (e.g., error correction, input confirmation) of the recognition results or the system's response to the speech input. Changes in the visual display itself provide a good form of feedback, but require driver head or eye movements to verify. Although any feedback will improve the driver's performance with the system, size limits on IVIS displays in the in-vehicle environment, as well as concerns about visual overload, suggest that auditory feedback should be used.


Table 6-8. Issues to Consider When Designing ASR Systems

Task-Related Issues	Environment-Related Issues	Operator-Related Issues
• Single versus dual task. • Workload. • Head movement requirements. • Driving situation (e.g., effects of stress). • Requirements for feedback. • Vocabulary requirements.	• External noise (e.g., traffic, road noise). • Internal noise (e.g., entertainment system, conversation). • Vibration. • Acceleration/deceleration G-forces.	• Age. • Articulation. • Regional accents. • Level of training. • Gender.

Discussion: Reference 1 discusses a variety of issues and research results associated with speech controls, and some of the guidelines above have been adapted from the design principles presented in reference 1 and, to a lesser extent, reference 2.

Reference 3 investigated ASR performance using a recorded, multispeaker database and seven candidate microphone positions. Evaluation criteria included signal-to-noise ratio (SNR) and recognition rate. A range of locations (e.g., center dashboard, ceiling near rearview mirror, visor on headliner in front of the driver, over driver head, and on the steering wheel) were investigated. Although all microphone positions were roughly near the driver, great variability was reported (between 0 percent and 10 percent) in error rates across the seven positions. The location on the forward portion of the vehicle headliner, right in front of the driver, gave the best combined results for both SNR and recognition rates. However, this issue has not been extensively studied and the optimum microphone location may vary across different in-vehicle applications.

Reference 4 investigated six options for providing feedback with an ASR device. The options included auditory or visual feedback, delay prior to feedback, and no feedback. In the study, subjects entered fields of data into an ASR device. These data consisted of alphanumeric characters, words, or numbers plus words, and were of varying length. With no feedback, only 70 percent of the entered fields were error-free; the average number of correctly entered fields across the feedback conditions (any feedback) was 97 percent. The authors noted some tradeoffs between visual and auditory feedback, with visual word feedback being optimal when a large visual display is available to the user. However, in situations with small displays or when visual overload of the user is a concern (such as in the in-vehicle environment), auditory feedback is recommended.

Design Issues: As noted in reference 1, key issues in the design and implementation of ASR systems include:

- Recognition accuracy: Lower accuracies will reduce system performance and user acceptance.
- Background noise: Ambient noise (traffic, radio, speech displays) can interfere with ASR system performance.
- Speech variability: Human speech varies considerably with respect to volume, frequency, pitch, and tone under different conditions, in addition to accents and regional variations. Speech variability can contribute to reduced recognition of speech.
- Task selection: Selection of tasks for which speech should be used must reflect task characteristics and a clear understanding of the tradeoffs associated with using speech controls vs. manual controls.

In addition, use of ASR does not ensure safe operation of an in-vehicle device. Even simple speech requires cognitive operations by the user (e.g., recalling phone numbers). In general, ASR is best used as a redundant source of input by the driver (i.e., an alternate manual means should be provided to the driver as well).

Cross References:
Chapter 10: Sensory Modality Design Tool

References:

1. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., and Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
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TIMING OF AUDITORY NAVIGATION INFORMATION

Introduction: The timing of auditory navigation information refers to the time or distance at which the in-vehicle navigation system should present an auditory instruction to the driver before an approaching navigation maneuver (e.g., a required turn).

Design Guidelines

- For maneuvers defined as leaving the current route (i.e., turning onto a side road), the timing of the auditory guidance instruction can be based on the equations provided below.
- It may be advisable to implement the equation for "preferred maximum distance." An instruction given slightly too early is preferable to one given too late.
- When the distance between two subsequent maneuvers is less than the minimum preferred distance for that speed, the instructions are "stacked" (given during a single message).

EQUATIONS[1]

Preferred Minimum Distance = (Speed x 1.637) + 14.799 (9)

Ideal Distance = (Speed x 1.973) + 21.307 (10)

Preferred Maximum Distance = (Speed x 2.222) + 37.144 (11)

[1] where speed is in km/h and distances are in meters

Example of the Suggested Timing for Navigational Information

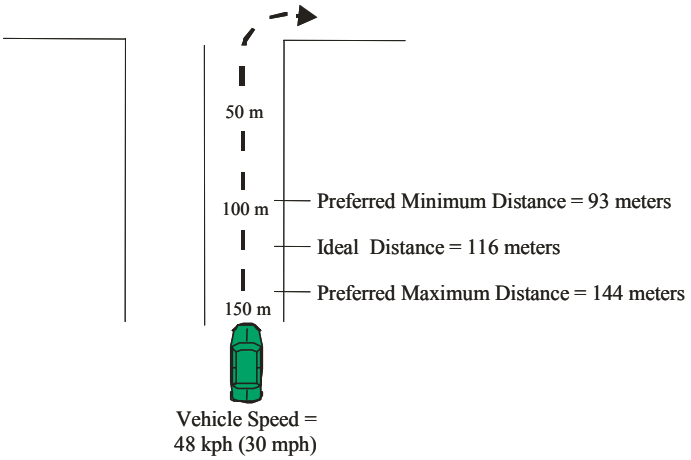

Figure 6-4. Equations for Determining the Appropriate Timing of an Instruction

Discussion: In reference 1, subjects were asked to give a subjective rating of the timeliness of auditory navigation instructions (1 = much too early to 6 = much too late). From the subjects' ratings, regression lines were plotted. Three separate equations were developed for calculating the distance at which navigation information should be given regarding an approaching turn onto a side road, while traveling at different speeds.

Reference 2 conducted a similar study aimed at determining the last possible moment at which a subject would feel comfortable hearing an auditory navigational instruction. The results of this study indicated that, traveling at speeds of 65 kph (40 mph), the recommended distance for giving navigational instructions before a turn is 137 meters (450 feet). However, it is necessary to make adjustments for other speeds (15 feet for each mile per hour/4.58 meters for each kilometer per hour); age of driver (up to 36 meters (119 feet)); the direction of turn, left or right (left turns require more warning distance); and gender of the driver. The results of this study are similar to those found in reference 1 but were determined to be more difficult to apply to the general driver population.

Design Issues: The applicability of these guidelines to visual guidance messages is uncertain. Since visual information (with no accompanying auditory alert) is likely to be perceived later than auditory messages, the distances recommended above may have to be increased somewhat to account for this delay. Turning off the current route is only one type of maneuver. Many other types (i.e., turning at a T-intersection, or an existing freeway) should be studied separately to determine which factors will affect them. The results of these studies could then be combined with the above guidelines to determine the appropriate timings for any possible type of combination of maneuvers.

In reference 3, it was recommended that if two maneuvers are less than 10 seconds apart, the two instructions should be given together, before the first maneuver. This is referred to as "stacking" the messages. Reference 1 gave a similar recommendation, stating that when the distance between two subsequent maneuvers is less than the minimum preferred distance for that speed, the instructions should be stacked.

References:

1. Ross, T., Vaughan, G., and Nicolle, C. (1997). Design guidelines for route guidance systems: Development process and an empirical example for timing of guidance instructions. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 139-152). Mahwah, NJ: Lawrence Erlbaum Associates.
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PERCEIVED ANNOYANCE OF AUDITORY SIGNALS

Introduction: Perceived annoyance of auditory signals refers to the subjective annoyance associated with particular signal characteristics. Although many sound parameters that increase urgency also increase annoyance careful design can create highly urgent sounds that are not overly annoying. The goal is to minimize the annoyance associated with a warning, balanced by the need to match the urgency of the signal to the urgency of the situation. This is called "annoyance tradeoff" and should be considered in signal design.

Design Guidelines

- For signals to be perceived as appropriate, highly urgent sounds should be used for highly critical situations.
- For signals to be perceived as appropriate, low annoyance sounds should be used for benign situations.
- Sound characteristics of pulse duration, burst density, sound type, and speed all increase perceived urgency more than perceived annoyance.

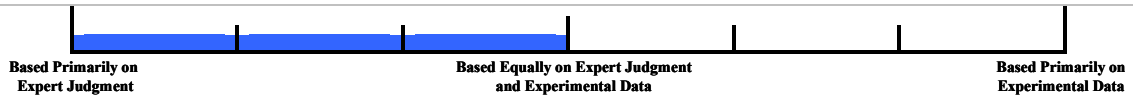

Table 6-9. Sound Characteristics that Increase Urgency, While Having a Modest Effect on Annoyance

CHARACTERISTIC	EFFECT ON URGENCY	EFFECT ON ANNOYANCE
Duration of sound (Pulse)	Longer >> more urgent	Longer > more annoying
Burst density	High >> more urgent	High > more annoying
Speed	Faster >> more urgent	Faster > more annoying

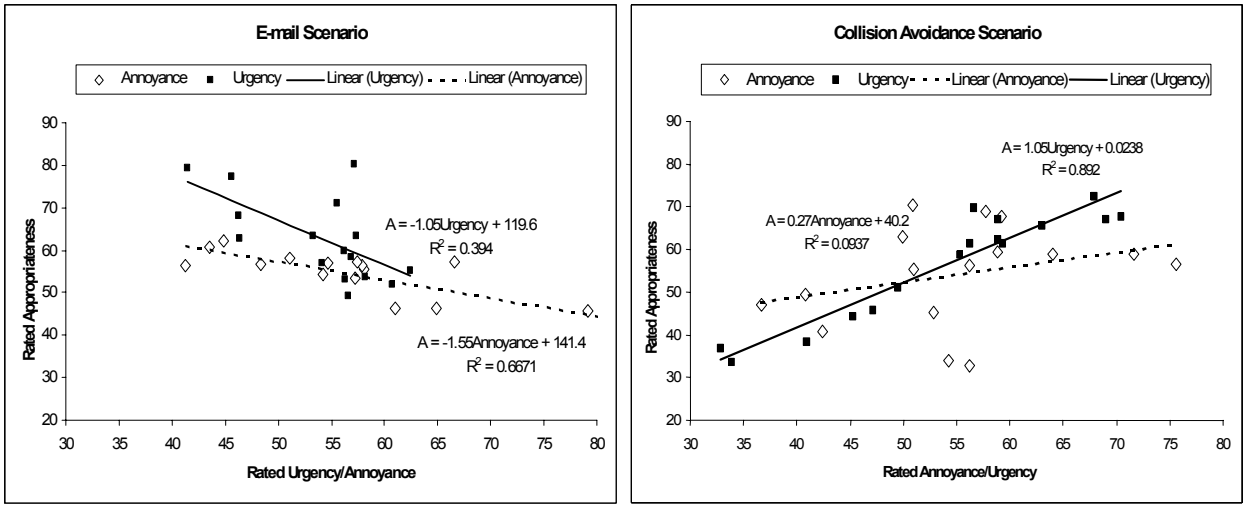

Figure 6-5. Appropriateness Depends on Perceived Annoyance for Benign Situations (e.g., e-mail notification), Whereas Appropriateness Depends on Perceived Urgency for Highly Critical Situations (e.g., collision avoidance)

Discussion: Substantial research has shown that sound parameters can effect perceived urgency (reference 1). The urgency mapping principle states that the urgency of the sound should a match the urgency of its referent. Like urgency, annoyance is systematically affected by sound parameters (references 2 and 3). Recently, research has shown that perceived annoyance of a sound is not completely dependent on the parameters that affect urgency (reference 4). Some sound parameters, such as those listed in the table in the guideline, can increase urgency substantially, while increasing annoyance relatively little. Using these parameters, it is possible to design a highly urgent sound that is less annoying than other sounds with the same perceived urgency. In general, design of highly urgent signals involves a tradeoff between urgency and annoyance, but some sound parameters can help minimize the annoyance of highly urgent sounds.

Recent results also show that the importance of annoyance is greater when designing sounds for benign alerts (reference 4). Perceived annoyance is a strong predictor of perceived appropriateness for auditory signals for benign events, whereas perceived urgency is a strong predictor of perceived appropriateness for auditory signals for critical events. The figure in the guideline shows that this relationship is quite robust, with perceived annoyance accounting for 67 percent of the variance of perceived appropriateness for email alerts and only 9 percent of the variance for a collision avoidance warning. Conversely, perceived urgency accounts for almost 90 percent of the variance of perceived appropriateness of collision avoidance warnings. This relationships shows that designing to minimize annoyance can be as critical as designing to map urgency.

Design Issues: Sound perception and perceived urgency and annoyance are somewhat dependent on the context and intended message of the signal (reference 5). This makes it critically important to evaluate the sounds generated using these guidelines in the driving context. Even using imagined driving scenarios in a laboratory situation affected the perceived urgency and annoyance of sounds (reference 4). In addition, urgency mapping and the annoyance tradeoff are only two considerations in creating useful auditory alerts. A critical consideration for a situation that contains multiple alerts is the ability of drivers to discriminate and recognize multiple auditory signals, as described earlier in the section *Design of Complex Tones*.

Cross References:
The Auditory Presentation of In-Vehicle Information, p. 6-1; *Design of Complex Tones*, p. 6-8; *Perceived Urgency of Auditory Signals*, p. 6-16

References:
1. Edworthy, J., Loxley, S., and Dennis, I. (1991). Improving auditory warning design - Relationship between warning sound parameters and perceived urgency. *Human Factors,* 33(2), 205-231.
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5. Edworthy, J., and Adams, A. (1996). *Warning design: A research prospective*. Bristol, PA: Taylor and Francis.

CHAPTER 7: EVALUATING IN-VEHICLE ICONS

OVERVIEW OF GENERAL PROCEDURES FOR EVALUATING IN-VEHICLE ICONS

Introduction: Evaluating icons refers to the general process of determining whether an icon, or an integrated set of icons, meets specific criteria in areas such as legibility, recognition, interpretation, and driver preferences. Developing useful and effective icons requires evaluation. A rigorous and iterative evaluation phase in icon design increases the likelihood that the implementation of the icon in the in-vehicle environment will improve driving and system performance and not negatively impact driver safety.

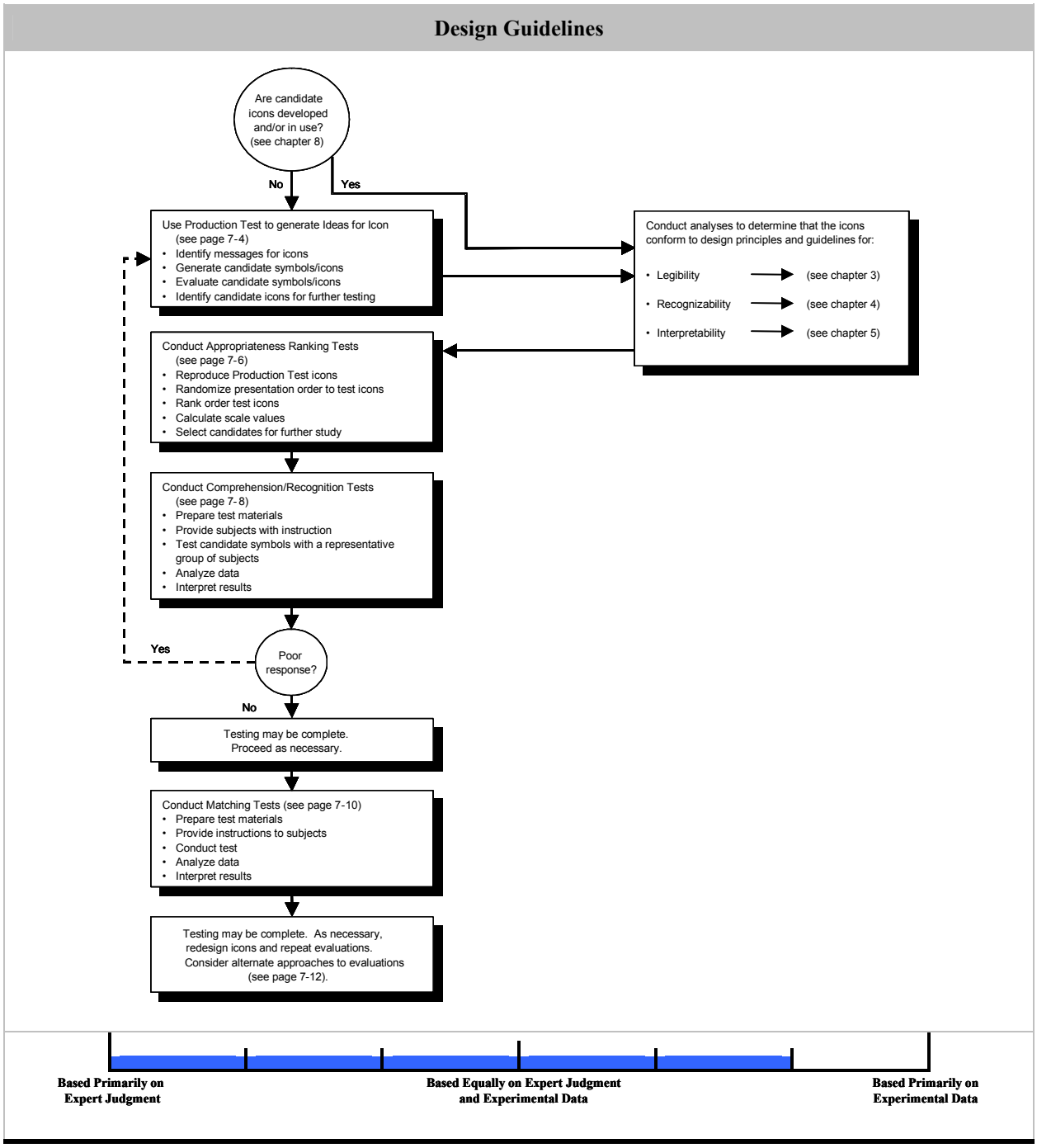

Figure 7-1. Overview of Procedures for Evaluating In-Vehicle Icons

Discussion: General procedures for evaluating icons have been presented in a number of data sources, including references 1, 2, 3, and 4. Importantly, the procedures outlined in this chapter reflect an integrated approach to icon evaluation. That is, each evaluation procedure (Production Test, Appropriateness Ranking Test, Comprehension/ Recognition Test, and Matching Test) addresses different research objectives and represents a key step in an overall process of developing legible, recognizable, and interpretable in-vehicle icons.

Evaluations of individual icons may not require going through the entire evaluation process. For example, if the icon development team has 3-5 strong candidate icons in-hand for a particular message, then the Production Test and the Appropriateness Ranking Test may not be needed. Similarly, if high levels of comprehension are obtained in the Comprehension/Recognition Test, then the Matching Test may not be needed.

Reference 4 provides guidelines for the development and evaluation of hazard and safety symbols. Many of the guidelines contained in reference 4 for the graphic design of symbols are general, and the recommendations provided for specific symbols are not for in-vehicle applications. However, some of the symbol evaluation procedures suggested in reference 4 are similar to those contained here. Some key differences between the guidelines presented here and those presented in reference 4 are: (1) Production Test is not called out as a formal procedure in reference 4; evaluations begin by selecting or gathering "existing symbol alternatives"; (2) An Appropriateness Ranking procedure is also not specified; instead, a comprehension estimation procedure (in which subjects estimate the percentage of the driving population that would understand a candidate icon) is used to eliminate poor candidates; (3) Criteria for acceptance following an open-ended Comprehension Test is 85 percent (versus the ISO criteria of 66 percent), with a maximum of 5 percent critical confusions; and (4) a Matching Test is not discussed.

While a subset of these evaluation procedures (as well as the alternate procedures described on pages 7-4 through 7-13) may be used, the IVIS developer should be aware of the limitations inherent in such an approach. That is, key issues associated with the effectiveness of a given icon may not be addressed without a complete, integrated approach to in-vehicle icon evaluation.

Design Issues: All evaluations of in-vehicle icons should be performed using test subjects who are representative of the driving public. Key demographic variables include age and gender. Age effects, in particular, can be expected for icon evaluations. Thus, individual evaluations should use a mix of younger and older test subjects. Also, representative non-English speakers should be included in testing.

Cross References:
General Development Process for In-Vehicle Icons, p. 2-2; *Production Test*, p. 7-4; *Appropriateness Ranking Test*, p. 7-6; *Comprehension/Recognition Test*, p. 7-8; *Matching Test*, p. 7-10; *Additional Symbol Evaluation Approaches*, p. 7-12

References:

1. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.
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3. Collins, B. L. (1982). *The development and evaluation of effective symbol signs*. Washington, DC: U.S. Department of Commerce (NBS Building Science Series, 141).
4. American National Standards Institute. (1998). *American national standard criteria for safety symbols, ANSI Z535.3*. Washington, DC: NEMA.

PRODUCTION TEST

Introduction: The production test refers to an icon evaluation approach in which a broad range of candidate symbols for a concept or referent (i.e., in-vehicle message) are generated. It is used when no symbols for a given message exist (reference 1). In this test, subjects are asked to draw symbols that they think represent a particular message. The output of the production test is a number of graphic or symbolic representations of a message that are considered effective and comprehensible by individual subjects. The production test will not result in a final icon selection. It is used to generate candidate symbols/icons only.

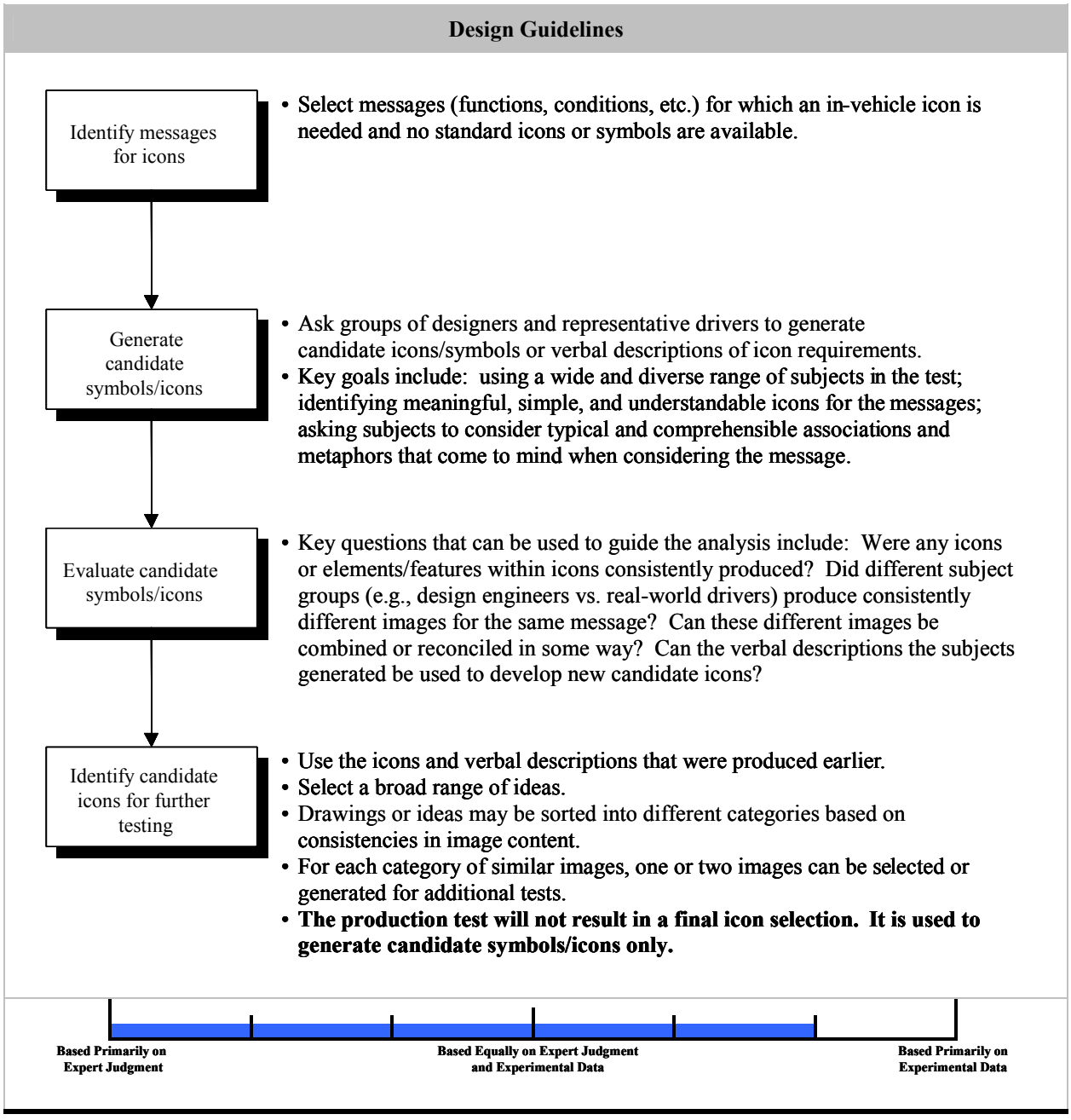

Figure 7-2. Production Test

Discussion: Empirical testing of candidate icons requires a variety of candidate symbols to present to subjects. The production test has been identified by reference 1 as a key step in icon development and an important means for generating a wide range of images for subsequent testing.

Reference 2 used a production test to generate ideas for symbols for common in-vehicle systems (coolant, fuel, air, oil, transmission, hydraulic, and brake), and specific conditions associated with the system (fluid level, temperature, pressure, and filter). This process generated a wide variety of candidate symbols. Importantly, variation across the symbols reflected characteristics of the subjects themselves. Some were serious, well thought out, and detailed; others were humorous and less thoughtful. Many reflected the type of work performed by the subjects, such as the mechanistic and function-oriented drawings made by subjects who were engineers.

Design Issues: The production test is not, by itself, a sufficient means to validate icons or symbols. The overall goal of the production test is to create a number of different candidate symbols as input for the more systematic evaluation approaches such as the comprehension/recognition test. In addition, the production test relies on the participants' ability to conceptualize the referent and generate an icon that includes the attributes of the referent needed for a comprehensible icon. With complex or novel concepts, this may not be an efficient and effective process for icon development.

An alternative is to use knowledge elicitation and concept mapping techniques to identify the elements of a comprehensible icon—that is, to conduct structured focus groups or one-on-one interviews with designers to elicit ideas about candidate icons. The objective of concept mapping, as applied to icon development, is to identify attributes of the referent that uniquely specify it and are commonly associated with it. Several structured processes exist to support this activity (see references 3, 4, and 5). In general, these processes begin by identifying concepts associated with a particular activity or system (e.g., in-vehicle routing and navigation). Once general concepts are identified, participants are queried to define distinguishing attributes and relationships. An example question might be: "How would you describe this item?" Once attributes and their relationships have been defined, a series of queries is used to refine them. Example questions might be: "Are there characteristics of this item that are not included in the list?" or "What are the most relevant characteristics in identifying this item?" Attributes identified by several users can be combined to define the features required to enhance icon comprehension. This process can be performed by manually sorting and combining the participants' responses, or by using sophisticated statistical techniques, such as factor and cluster analysis (see references 6 and 7). All evaluations of in-vehicle icons should be performed using test subjects who are representative of the driving public. Key demographic variables include age and gender. Age effects, in particular, can be expected for icon evaluations. Thus, individual evaluations should use a mix of younger and older test subjects.

Cross References:
Overview of General Procedures for Evaluating In-Vehicle Icons, p. 7-2; *Appropriateness Ranking Test*, p. 7-6; *Comprehension/Recognition Test*, p. 7-8; *Matching Test*, p. 7-10; *Additional Symbol Evaluation Approaches*, p. 7-12

References:
1. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.
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APPROPRIATENESS RANKING TEST

Introduction: The purpose of the appropriateness ranking test is to screen the candidate symbols generated during the production test and select the best for further testing. Essentially, subjects are asked to rank order a set of candidate symbols for a message with respect to their relative appropriateness. Once these ranking data have been gathered, the three candidate symbols with the highest ranking are typically selected for further testing.

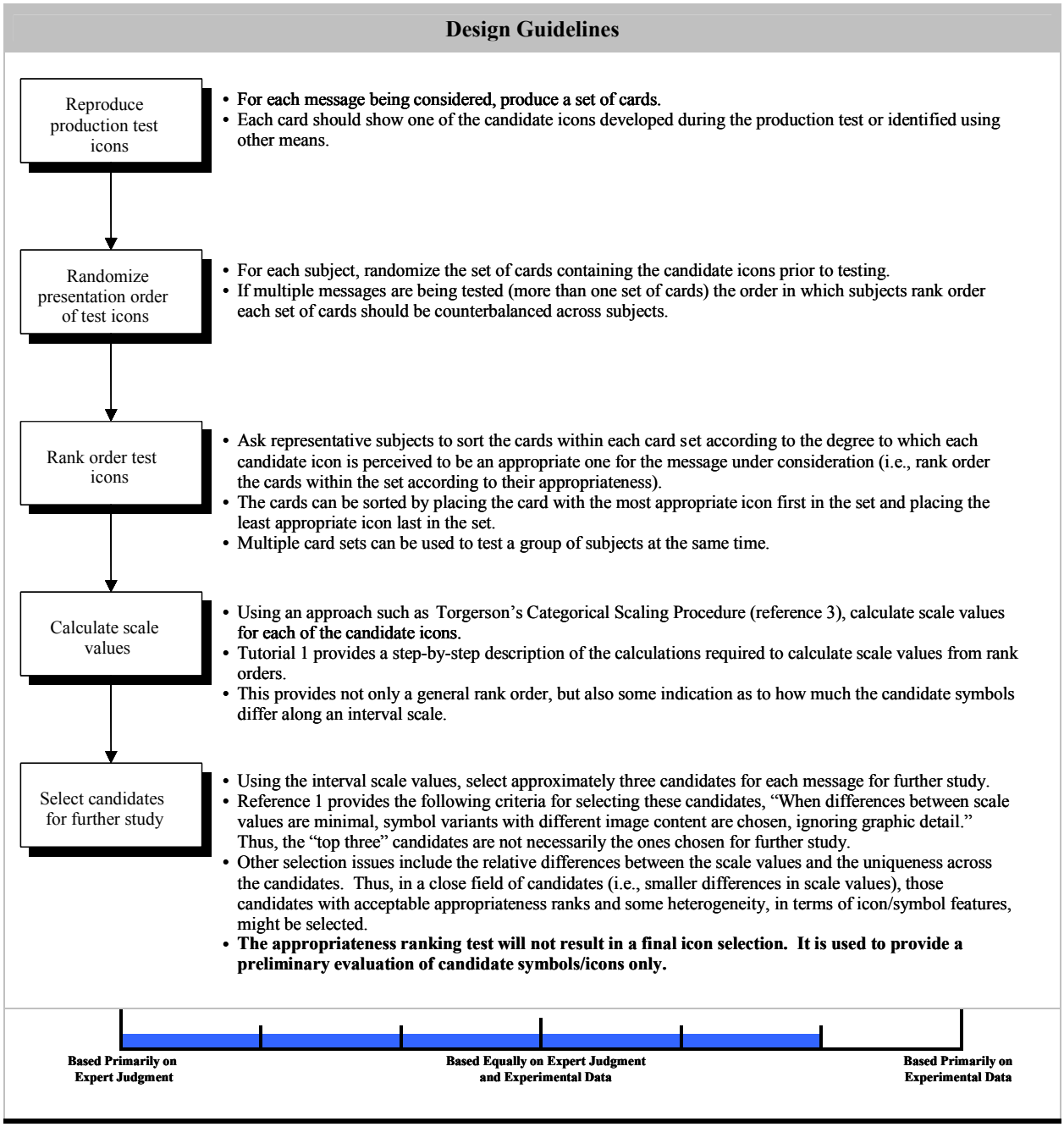

Figure 7-3. Appropriateness Ranking Test

Discussion: A preliminary screening of candidate icons for a message is necessary to make further testing of the icons feasible and cost-effective (see also reference 1). The appropriateness ranking test provides an objective, quick, low-cost approach to the task of reducing what can be a large number of candidate icons to a more manageable number of high-potential candidates.

The appropriateness ranking test has been successfully used in previous symbol development efforts. For example, in reference 2, six messages were tested using the procedure described above, with between eight and 35 candidate symbols being rank ordered for each message. In this study, the results of the appropriateness ranking test allowed the researchers to reduce, in a systematic manner, the number of these candidates to about three per message.

The advantage of converting rank order data to an interval scale of perceived appropriateness is that rank orders alone do not indicate the relative differences among judged stimuli. Thus, mean ranks suggest that differences in perceived appropriateness between, for example, stimuli 1 and 2 are the same as differences between stimuli 2 and 3. The Categorical Scaling Procedure provides the interval data necessary to make informed decisions regarding the true relative appropriateness of candidate icons.

Design Issues: When developing candidate icons for the test, consider that driver perception and performance will vary as a function of the medium used to present the test stimuli. That is, display parameters such as resolution, production of color, and luminance can affect responses. In general, the color, brightness, resolution, and size of test icons should be as close as possible to how the icons will be viewed by drivers in the in-vehicle environment.

As noted in reference 4, the appropriateness ranking test should not be used to make final selections of icons. Considerable experimental data suggest that more detailed, concrete icons are consistently judged to be more appropriate and given higher ranks than more abstract icons. However, highly detailed icons may lead to increased response times, are more easily confused with other icons, and are not always consistent with the need to provide simple visual information through in-vehicle displays. Thus, the appropriateness ranking test helps to identify candidate icons based on image content only, and cannot address more complex issues such as the comprehensibility of icons in an operational environment.

Often, subjects will be unable to distinguish the appropriateness of a given icon from another. Subjects should be instructed that the same ranking (or a tie) can be given to more than one candidate icon. All evaluations of in-vehicle icons should be performed using test subjects who are representative of the driving public. Key demographic variables include age and gender. Age effects, in particular, can be expected for icon evaluations. Thus, individual evaluations should use a mix of younger and older test subjects.

Cross References:
Overview of General Procedures for Evaluating In-Vehicle Icons, p. 7-2; *Production Test*, p. 7-4; *Comprehension/Recognition Test*, p. 7-8; *Matching Test*, p. 7-10; *Additional Symbol Evaluation Approaches*, p. 7-12; *Tutorials: Analysis of Rank Order Data*, p. 9-1

References:
1. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby & H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.
2. Easterby, R. S., and Zwaga, H. (1976). *Evaluation of public information symbols, ISO tests: 1975 series* (Report AP 60). Birmingham, UK: Applied Psychology Department, University of Aston at Birmingham.
3. Torgerson, W. S. (1965). *Theory and methods of scaling*. New York: J. Wiley & Sons.
4. Hakiel, S. R. (1991). *Evaluating icons for human-computer interfaces* (Report No. HF 144). Hursley Park, Winchester, UK: IBM UK Laboratories Ltd.

COMPREHENSION/RECOGNITION TEST

Introduction: The comprehension/recognition test refers to an evaluation technique that provides a means to determine which of a number of candidate icons/symbols for a concept are best understood by a sample of subjects who represent the user population. During this test, an icon/symbol is presented to subjects, the context of the icon/symbol is specified (i.e., where they might expect to see the icon, according to reference 1), and subjects are asked to name the object, location, or activity associated with the icon/symbol.

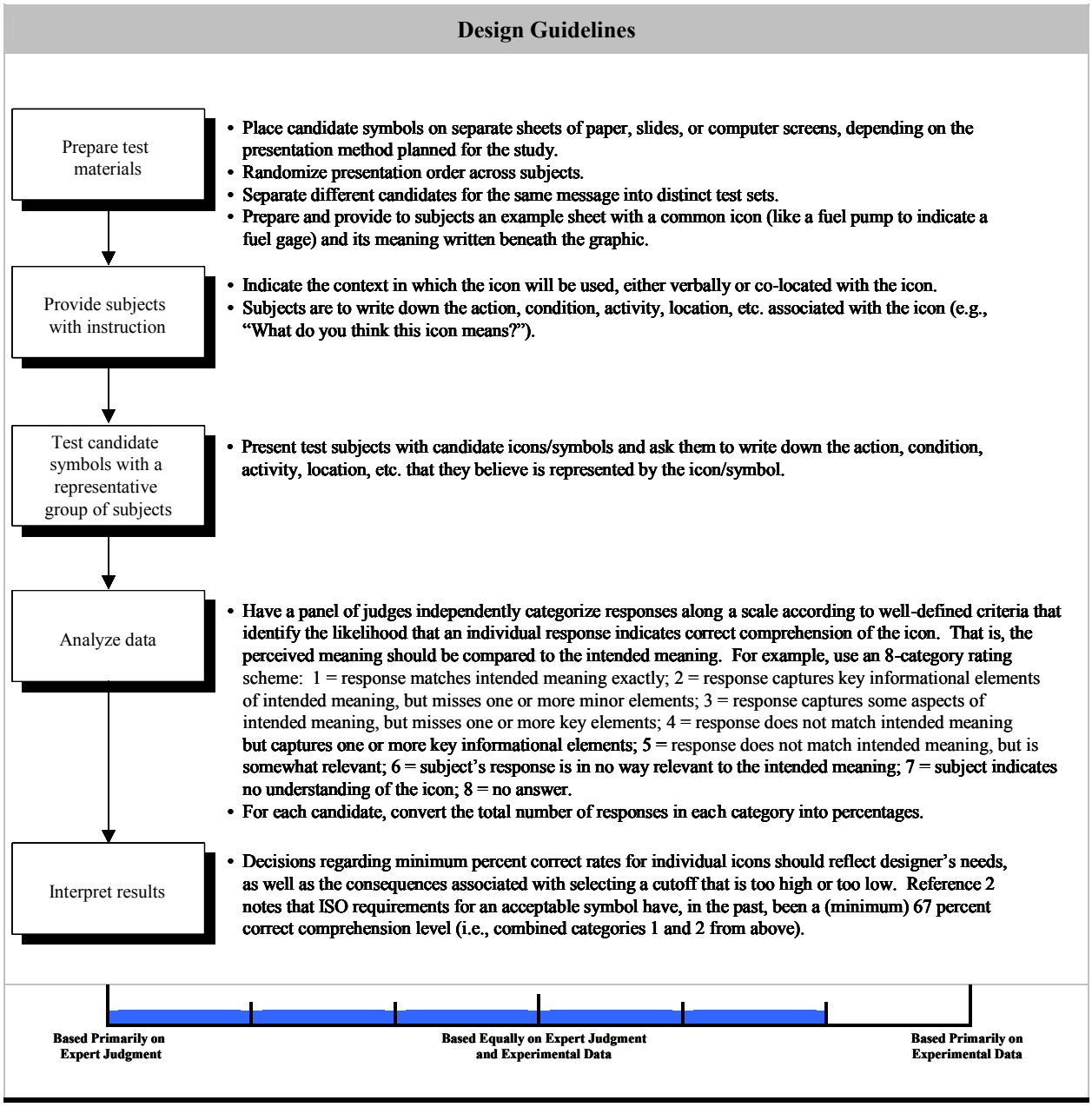

Figure 7-4. Comprehension/Recognition Test

Discussion: Reference 1 has been developed as a standard procedure for developing and testing public information symbols. This standard provides a highly detailed set of instructions for testing symbols. Some computational procedures in reference 1, however, are unnecessarily complex and the guidelines presented on the preceding page represent a summary of the procedures listed in references 1 and 3.

Design Issues: When developing candidate icons for the test, consider how driver perception and performance will vary as a function of the medium used to present the test stimuli. That is, display parameters such as resolution, production of color, and luminance can affect responses. In general, the color, brightness, resolution, and size of test icons should be as close as possible to how the icons will be viewed by drivers in the in-vehicle environment.

All evaluations of in-vehicle icons should be performed using test subjects that are representative of the driving public. Key demographic variables include age and gender. Previous studies have indicated that significant differences exist between younger people and older people in their ability to comprehend symbols (references 4 and 5). Therefore, subjects should be representative of the user population (e.g., half between the ages of 18 and 40 and the other half over 55 years).

In real-world driving, icons are presented in the context of certain in-vehicle capabilities and driving circumstances. As such, evaluations of in-vehicle icons should include a description of the context in which icons will be presented and used. However, icon evaluations should avoid providing either too little or too much context to experimental subjects. If too little context is provided, unrealistically low comprehension scores may result from subjects' being unable to connect a visual icon with its many possible meanings. Too much context may yield unrealistically high comprehension scores because the subjects have been cued for a certain response by the specificity of the context. Both extremes should be avoided. In chapter 9, a tutorial entitled "Providing Subjects with Context During Icon Evaluations" provides both procedures and examples associated with providing appropriate context to experimental subjects.

Candidate icons should be tested individually, as the focus is on testing absolute comprehension/recognition for individual icons. The goal is not to test confusability across icons (as it is in the matching test).

Cross References:
Overview of General Procedures for Evaluating In-Vehicle Icons, p. 7-2; *Production Test*, p. 7-4; *Appropriateness Ranking Test*, p. 7-6; *Matching Test*, p. 7-10; *Additional Symbol Evaluation Approaches*, p. 7-12;
Tutorials: Providing Subjects with Context During Icon Evaluations, p. 9-11

References:
1. ISO/DIS 9186. (1988). *Procedures for the development and testing of public information symbols*. Geneva, Switzerland: ISO.
2. Wolff, J. S., and Wogalter, M. S. (1998). Comprehension of pictorial symbols: Effect of context and test method. *Human Factors,* 40(2), 173-186.
3. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.
4. Dewar, R. E., Kline, D. W., and Swanson, A. H. (1994). Age differences in comprehension of traffic sign symbols. *Transportation Research Record* 1456, 1-10.
5. Saunby, C. S., Farber, E. I., and DeMello, J. (1988). Driver understanding and recognition of automotive ISO symbols. *SAE Technical Paper Series* (No. 880056). Warrendale, PA: Society of Automotive Engineers.

MATCHING TEST

Introduction: After the best or most appropriate design for a symbol has been determined, it is important to examine how well that symbol will work within a set and whether the many symbols within the set, can be discriminated from one another without confusion. To do this, a Matching Test is performed. Subjects are shown a sheet with all of the symbols from a set on it, arranged in a matrix, and told the context under which they would use these symbols. Next, subjects are given a referent name and asked to indicate on the matrix which one of the symbols stands for that particular referent. The outcome of the matching test is two measures of symbol effectiveness: the number of correct choices of a particular symbol, and the degree of confusion among symbols

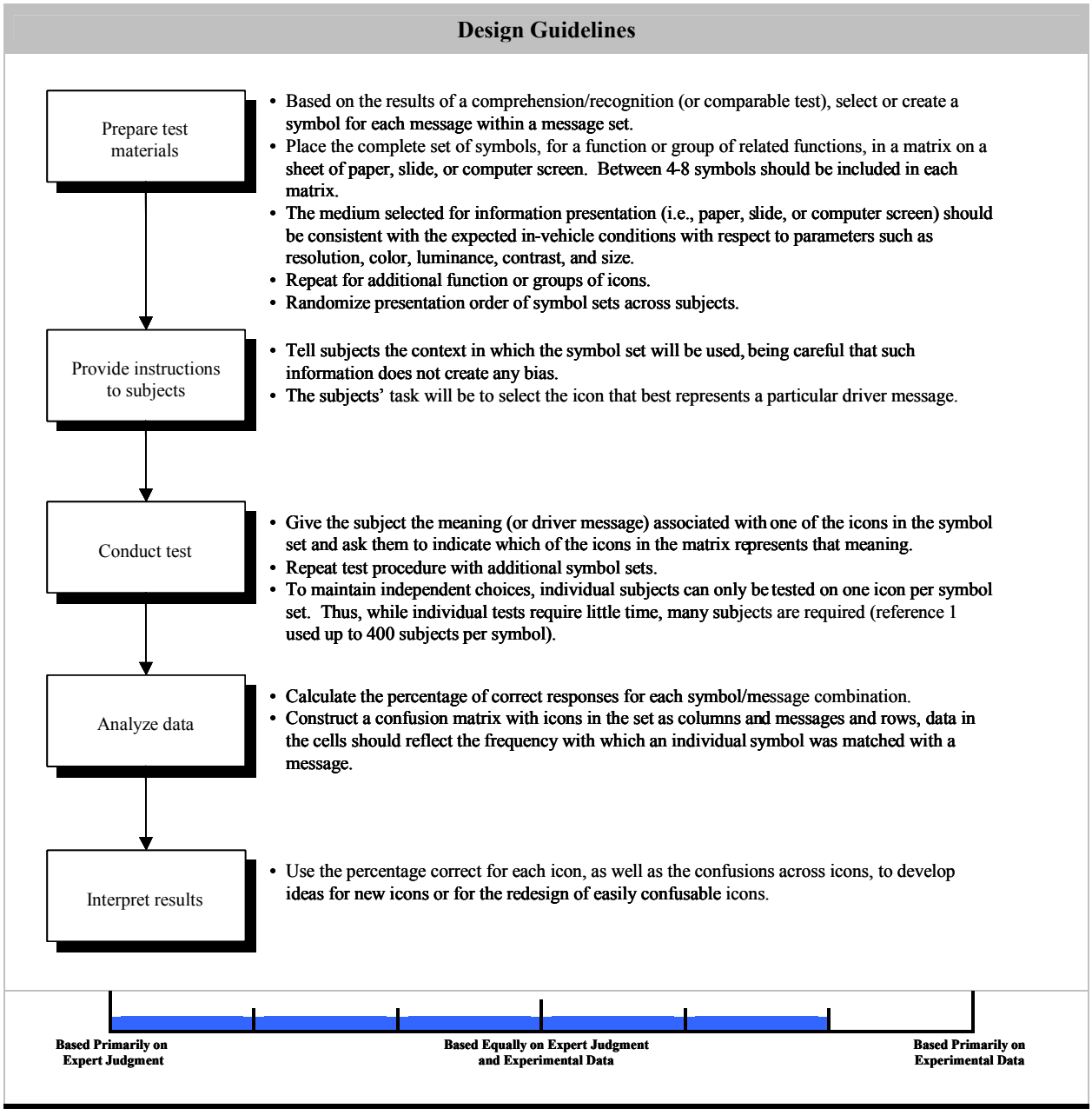

Figure 7-5. Matching Test

Discussion: The Matching Test measures the specific association between the content of an icon and an in-vehicle message when the icon is presented to a subject at the same time as other icons within an icon set (see also reference 1). Subjects are only tested on one icon per symbol set to avoid non-independence of their choices. If multiple icons within a symbol set were tested, individual choices would be dependent on previous choices, thus confounding the results.

Data from the Matching Test can be represented in two ways. First, indicate the number of correct choices for a particular symbol by calculating the percentage of correct responses for each symbol/message combination. Second, construct a table with icons in the set as columns and messages as rows. Cell entries can show overall percentages associated with the subjects responses. Thus, incorrect as well as correct responses are depicted in the table (also called a confusion matrix).

If the scores from the Matching Test are acceptable to the design team, the testing may be complete. However, if some scores are too low, additional icon development and evaluation may be needed.

Design Issues: When developing candidate icons for the test, consider that driver perception and performance will vary as a function of the medium used to present the test stimuli. That is, display parameters such as resolution, production of color, and luminance can affect responses. In general, the color, brightness, resolution, and size of test icons should be as close as possible to how the icons will be viewed by drivers in the in-vehicle environment.

Importantly, the Matching Test does not measure any absolute trait of individual symbols, nor measure absolute comprehension or recognition associated with a candidate icon. All measures relate to subjects' ability to match an icon with a message within the context of other related icons. In this regard, icon developers often wish to develop families or groups of icons that share some common purpose or meaning (e.g., collision avoidance). Groups or families of icons typically share some common design element such as color, border, size, or graphic style. The Matching Test may provide an ideal method for evaluating subjects' ability to discriminate between related and nonrelated icons.

In real-world driving, icons are presented in the context of certain in-vehicle capabilities and driving circumstances. As such, evaluations of in-vehicle icons should include a description of the context in which they will be presented and used. However, icon evaluations should avoid providing either too little or too much context to experimental subjects. If too little context is provided, unrealistically low comprehension scores may result from subjects' being unable to connect a visual icon with the many possible icon meanings. If too much context is provided, unrealistically high comprehension scores may result because the subjects have been cued for a certain response by the specificity of the context. Both extremes should be avoided. In chapter 9, a tutorial provides both procedures and examples associated with providing appropriate context to experimental subjects.

Cross References:
Overview of General Procedures for Evaluating In-Vehicle Icons, p. 7-2; *Production Test*, p. 7-4; *Appropriateness Ranking Test*, p. 7-6; *Comprehension/Recognition Test*, p. 7-8; *Additional Symbol Evaluation Approaches*, p. 7-12; *Tutorials: Providing Subjects with Context During Icon Evaluations*, p. 9-11

References:
1. Zwaga, H., and Easterby, R. S. (1984). Developing effective symbols for public information. In R. Easterby and H. Zwaga (Eds.), *Information design: The design and evaluation of signs and printed material* (pp. 277-297). New York: J. Wiley & Sons.

ADDITIONAL SYMBOL EVALUATION APPROACHES

Introduction: In addition to the evaluation approaches described in the previous guidelines in this chapter, a number of additional approaches have been suggested and successfully used to evaluate the effectiveness of icons.

Design Guidelines

- The evaluation technique selected to assess the effectiveness of candidate icons should be consistent with the goals and constraints of a particular system development effort. The table below summarizes a range of alternative evaluation approaches, gives the advantages and disadvantages associated with each, and provides references for designers to go to for more detailed information.

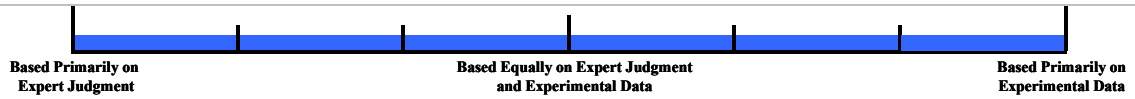

Table 7-1. Summary of Additional Symbol Evaluation Approaches

Evaluation Technique	Description	Advantage/Disadvantage	References
Rating task	Subjects are asked to determine the degree to which a symbol suggests or communicates its designated name.	Reference 1 found that results of the rating task were well correlated with the results of the reaction time task (see below); however, ratings are easier to obtain and more statistically efficient.	Reference 1
Reaction time task (speed of comprehension)	Subjects are given a referent, then shown a slide of one of the symbols and asked to indicate whether the referent and the symbol are the "same." The amount of time taken to make the response is recorded as reaction time.	Reaction time in a discrimination task is influenced by individual differences and decreases markedly with learning (reference 1).	Reference 1 Reference 2
Identification time task	Subjects are shown slides of traffic signs (in both text and symbol format) and are asked to identify verbally the message that is being presented. Their response time is recorded as identification time.	Relatively inexpensive and easy means for obtaining information about the adequacy of symbols.	Reference 3 Reference 4
Semantic differential method	Subjects rate symbols on 12 different adjective pairs, such as weak-strong, strange-familiar. A factor analysis is then performed to evaluate the results.	The factors included: evaluative, potency, activity, and understandability. For all but understandability, it is difficult to determine the design issues that are associated with the factors.	Reference 5 Reference 6
Modified semantic differential method	This method uses adjective pairs that are more specific and relevant to designers, such as balanced-unbalanced, confusing-clear, etc.	Reference 5 compared this method with traditional but logistically expensive measures, such as reaction time and glance legibility, and found this technique to provide a simple, inexpensive, and valid measure of comprehension.	Reference 7

Discussion: In many icon and in-vehicle display development efforts, there is insufficient time or budget available to conduct the sequential, inter-dependent series of evaluations described in the preceding design guidelines. This design guideline, therefore, identifies additional evaluation techniques that have been used and described in the human factors and icon development literature.

Design Issues: The selection of an appropriate evaluation approach should reflect specific empirical objectives, as well as the driver messages, expected driving context, and design constraints associated with individual in-vehicle icons or symbols. For example, if human response times to a particular icon are important for its effectiveness, then evaluation should include dependent measures that will capture this information. In this particular case, the optimal icons will be those that satisfy icon comprehension and discrimination with the shortest response time. The evaluation of other icons or sets of icons may focus more on different types of measures and thus will require a completely different type of evaluation process.

All evaluations of in-vehicle icons should be performed using test subjects who are representative of the driving public. Key demographic variables include age and gender. Age effects, in particular, can be expected for icon evaluations. Thus, individual evaluations should use a mix of younger and older test subjects.

Cross References:
Overview of General Procedures for Evaluating In-Vehicle Icons, p. 7-2; *Production Test*, p. 7-4; *Appropriateness Ranking Test*, p. 7-6; *Comprehension/Recognition Test*, p. 7-8; *Matching Test*, p. 7-10

References:

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3. Dewar, R. E., and Ells J. G. (1974). Comparison of three methods for evaluating traffic signs. *Transportation Research Record*, 503, 38-47.
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CHAPTER 8: ICON COLLECTION

Introduction: Generating new icons is a time-consuming and error-prone task. Designers can save time and develop more effective icons if they can draw upon proven icon designs rather than create new ones. Unfortunately, icons for in-vehicle systems are not collected in a single location, but are dispersed over the internet, held in proprietary collections, and sold in large clip art collections. In addition, these icon sources are not organized in a way that can be easily matched to the functions and features of in-vehicle information systems. The Icon Collection seeks to overcome these difficulties by providing designers with a set of candidate icons organized according to the functions and characteristics of in-vehicle information systems.

The ideal situation would be one where a designer could simply take set of messages associated with an in-vehicle function and look up that function in the Icon Collection to identify the appropriate icon. Unfortunately, this is not possible. Many messages do not have icons associated with them, so new icons must be designed. Also, many candidate icons are obviously poor; existing icons may be useful only as bad examples or as inspiration for new designs. Over time, additional icons will be developed for more in-vehicle systems and the Icon Collection can be expanded; however, it will never offer a complete solution to the designer. The characteristics of a "good" icon depend on the particular system and implementation. The collection provides designers with a well-organized collection of "good" and "bad" candidate icons that can inspire them and reduce development time.

The Icon Collection is organized according to the functions of in-vehicle systems. Functions such as routing and navigation are composed of subfunctions such as trip planning and route guidance. Each subfunction may have several messages, such as "price ranges for lodging along route" and "total trip time" for the subfunction of trip planning. The table below lists the functions and subfunctions that describe in-vehicle information systems along with the page number associated with each function.

Categories of Icons Included in this Collection

For each message, the Icon Collection shows the source, an icon that matches the message, and comments regarding the source of the icon. For example, the extract below shows an icon for the message "Lodging" for trip planning. In some cases, the symbol was edited in some manner to make it more relevant to the referrent (e.g., text may have been added or symbols combined) and this is indicated in the "Notes" area.

ID#: 382

Message: Lodging

Source: Teague

Notes:

File: Lodging.jpg

The icons in the Icon Collection come from six sources: (1) the Internet, (2) commercially available clip art (e.g., Corel®), (3) noncommercial picture files available on the contractor's intranet (cited as "Clickart"), (4) the automotive electronics industry, (5) past and present research and development efforts in the area of driver information (example sources include: ISO, "Drawn" (drawn by the contractor), SODS (a project conducted for the National Highway Traffic Safety Administration (NHTSA) in 1995), and the MUTCD), and (6) Teague (an industrial design firm under subcontract to the contractor during this project).

Icon Details by Icon Type

Function: Augmented Signage
Roadway notification sign information
General

ID #: 119

Message: Added lane sign

Source: http://members.aol.com/rcmoeur/w4.html

Notes:

File: 2 up arrows.jpg

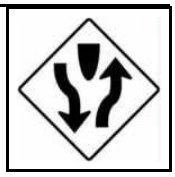
ID #: 264

Message: Divided highway (road) sign

Source: http://members.arttoday.com/

Notes: twolane06bw.jpg

File: 2 opposite arrows.jpg



ID #: 96

Message: Drawbridge

Source: http://members.arttoday.com/

Notes: drawbridge01bw.jpg, edited

File: drawbridge.gif

ID #: 354

Message: Lane reduction transition sign

Source: http://members.aol.com/rcmoeur/w4.html

Notes:

File: 2 lines.jpg

ID #: 262

Message: Merge sign

Source: http://members.aol.com/rcmoeur/w4.html

Notes:

File: split arrow.jpg

Function: Augmented Signage
Roadway notification sign information
General

ID #: 271

Message: Pedestrian crossing ahead

Source: http://members.aol.com/rcmoeur/rg.html

Notes:

File: man.gif

ID #: 65

Message: Percent of grade

Source: Corel ®

Notes:

File: hill.jpg

ID #: 366

Message: Railroad crossing

Source: http://members.aol.com/rcmoeur/rrsign.html

Notes:

File: double R.jpg

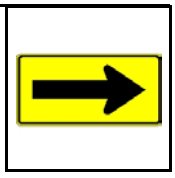
ID #: 42

Message: Sharp curve ahead

Source: http://www.dps.state.ak.us/dmv/DLMANUAL/pg44c.htm; http://members.aol.com/rcmoeur/w1.html

Notes:

File: right arrow-text.jpg



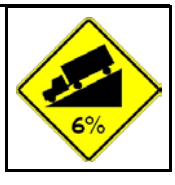
ID #: 14

Message: Steep downgrade

Source: http://members.aol.com/rcmoeur/w7.html

Notes:

File: truck on slope.jpg



Icon Details by Icon Type

Function: Augmented Signage
Roadway notification sign information
General

ID #: 183

Message: Tight ramp or intersection

Source: http://members.aol.com/rcmoeur/w1.html

Notes:

File: curved arrow.jpg

ID #: 351

Message: Turn signs

Source: http://members.aol.com/rcmoeur/w1.html

Notes:

File: right arrow.jpg

ID #: 139

Message: Winding road sign

Source: http://members.aol.com/rcmoeur/w1.html

Notes:

File: squiggly arrow.jpg

Function: Augmented Signage
Roadway regulatory sign information
General

ID #: 104

Message: No trucks

Source: http://members.arttoday.com/

Notes: notrucks01bw.jpg

File: NoTruck.jpg

ID #: 87

Message: Rock spray

Source: http://members.arttoday.com/

Notes: gravel04c.jpg, edited

File: rockspray.gif

Function: Augmented Signage
Roadway regulatory sign information
General

ID #: 414

Message: Speed limit 50

Source: http://www.dps.state.ak.us/dmv/DLMANUAL/pg429.htm

Notes:

File: SL 50.jpg

ID #: 268

Message: Stop ahead

Source: http://members.aol.com/rcmoeur/w3.html

Notes:

File: stop arrow.jpg

ID #: 228

Message: Yield

Source: Corel ®

Notes:

File: yield.jpg

ID #: 176

Message: Yield ahead

Source: http://members.aol.com/rcmoeur/r1.html

Notes:

File: yield arrow.jpg

Icon Details by Icon Type

Function: Automated/Adaptive Cruise Control Devices
Automated/adaptive cruise control
General

ID #: 195

Message: Adaptive cruise control engaged

Source: ISO

Notes:

File: AutomatedCruiseControl8A-1.jpg

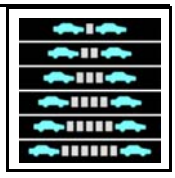
ID #: 216

Message: Adaptive cruise control engaged

Source: Industry

Notes:

File: GapWarn1.gif



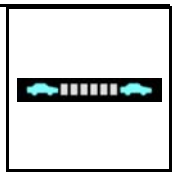
ID #: 31

Message: Adaptive cruise control engaged

Source: Industry

Notes:

File: GapWarn3.gif



ID #: 8

Message: Adaptive cruise control failure

Source: ISO

Notes:

File: AutomatedCruiseControl8A-2.jpg

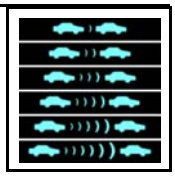
ID #: 114

Message: Adaptive cruise control not engaged

Source: Industry

Notes:

File: GapWarn2.gif



Function: Automated/Adaptive Cruise Control Devices
Automated/adaptive cruise control
General

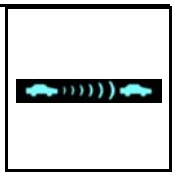
ID #: 393

Message: Adaptive cruise control not engaged

Source: Industry

Notes:

File: GapWarn4.gif



Function: Collision Avoidance Information
Braking devices
General

ID #: 206

Message: Brake service required

Source: Teague

Notes:

File: Brake warning.jpg

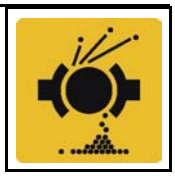
ID #: 68

Message: Brake service required

Source: Teague

Notes:

File: Warning brakes.jpg



Function: Collision Avoidance Information
Collision avoidance
General

ID #: 341

Message: Imminent collision warning

Source: Teague

Notes:

File: crash.jpg

Icon Details by Icon Type

Function: Collision Avoidance Information
Collision avoidance
General

ID #: 281

Message: Imminent collision warning

Source: SODS

Notes:

File: warning 1.jpg

ID #: 399

Message: Imminent collision warning

Source: SODS

Notes:

File: warning 2.jpg

ID #: 332

Message: Imminent collision warning

Source: SODS

Notes:

File: warning 3.jpg

ID #: 53

Message: Imminent collision warning

Source: SODS

Notes:

File: warning 4.jpg

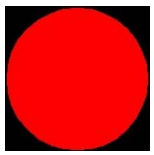
ID #: 172

Message: Imminent collision warning

Source: SODS

Notes:

File: warning 5.jpg



Function: Collision Avoidance Information
Collision avoidance
General

ID #: 303

Message: Traffic collision

Source: Industry

Notes:

File: trafficCollision.gif

Function: Collision Avoidance Information
Forward collision avoidance
General

ID #: 85

Message: Forward vehicle crash warning

Source: Teague

Notes:

File: Crash warning front.jpg

ID #: 326

Message: Forward vehicle crash warning

Source: ISO (proposed)

Notes:

File: ForwardCollisionAvoidance7C-1.jpg

ID #: 162

Message: Forward vehicle crash warning

Source: ISO (proposed)

Notes:

File: ForwardCollisionAvoidance7C-2.jpg

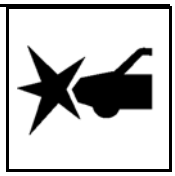
Icon Details by Icon Type

Function: Collision Avoidance Information
Forward collision avoidance
General

ID #: 293

Message: Forward vehicle crash warning

Source: ISO (proposed)



Notes:

File: ForwardCollisionAvoidance7C-3.jpg

ID #: 260

Message: Forward vehicle crash warning system failure

Source: ISO (proposed)

Notes:

File: ForwardCollisionAvoidance7C-4.jpg

ID #: 373

Message: Forward vehicle crash warning system failure

Source: ISO (proposed)

Notes:

File: ForwardCollisionAvoidance7C-5.jpg

ID #: 59

Message: Forward vehicle crash warning system failure

Source: ISO (proposed)

Notes:

File: ForwardCollisionAvoidance7C-6.jpg

Function: Collision Avoidance Information
Rear-end collision avoidance
General

ID #: 363

Message: Alert level

Source: Industry

Notes:

File: AlertLvl.gif

ID #: 385

Message: Imminent collision warning

Source: Teague

Notes:

File: Crash warning rear.jpg

ID #: 44

Message: Imminent collision warning

Source: Corel ®

Notes: edited

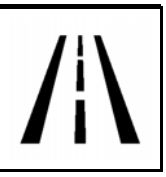
File: Head on.jpg

Function: Collision Avoidance Information
Road departure
General

ID #: 386

Message: Lane departure warning

Source: ISO (proposed)



Notes:

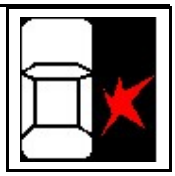
File: RoadDeparture7E-1.jpg

Icon Details by Icon Type

Function: Collision Avoidance Information
Side collision avoidance
General

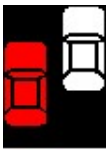
ID #: 296
Message: Imminent collision warning
Source: SODS
Notes:
File: Collision Left.jpg

ID #: 106
Message: Imminent collision warning
Source: SODS
Notes:
File: Collision Right.jpg

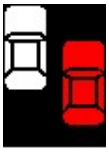


ID #: 37
Message: Imminent collision warning
Source: Teague
Notes:
File: crash 2.jpg

ID #: 116
Message: Imminent collision warning
Source: SODS
Notes:
File: Red car left.jpg



ID #: 349
Message: Imminent collision warning
Source: SODS
Notes:
File: Red car right.jpg



Function: Collision Avoidance Information
Side collision avoidance
General

ID #: 416
Message: Imminent collision warning
Source: SODS
Notes:
File: warning 6.jpg

ID #: 256
Message: No left turn
Source: SODS
Notes:
File: No left turn.jpg

ID #: 275
Message: No right turn
Source: SODS
Notes:
File: No right turn.jpg

ID #: 55
Message: Side obstacle warning
Source: ISO (proposed)
Notes:
File: LaneChange7F-1.jpg

ID #: 317
Message: Side obstacle warning
Source: ISO (proposed)
Notes:
File: LaneChange7F-2.jpg

Icon Details by Icon Type

Function: Collision Avoidance Information
Side collision avoidance
General

ID #: 306

Message: Side obstacle warning

Source: ISO (proposed)

Notes:

File: LaneChange7F-3.jpg

ID #: 407

Message: Side obstacle warning

Source: ISO (proposed)

Notes:

File: LaneChange7F-4.jpg

Function: Collision Avoidance Information
System status
General

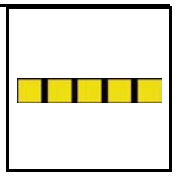
ID #: 235

Message: Cautionary warning

Source: SODS

Notes:

File: Yellow Horizontal.jpg



ID #: 74

Message: Cautionary warning

Source: SODS

Notes:

File: Yellow Stripes.jpg

ID #: 299

Message: Cautionary warning

Source: SODS

Notes:

File: Yellow Triangle.jpg

Function: Collision Avoidance Information
System status
General

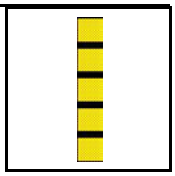
ID #: 372

Message: Cautionary warning

Source: SODS

Notes:

File: Yellow Vert.jpg



ID #: 4

Message: Lane departure warning system failure

Source: ISO (proposed)

Notes:

File: RoadDeparture7E-2.jpg

ID #: 421

Message: Lane departure warning system off or not available

Source: ISO (proposed)

Notes:

File: RoadDeparture7E-3.jpg

ID #: 378

Message: Side obstacle warning system failure

Source: ISO (proposed)

Notes:

File: LaneChange7F-5.jpg

ID #: 24

Message: Side obstacle warning system failure

Source: ISO (proposed)

Notes:

File: LaneChange7F-6.jpg

Icon Details by Icon Type

Function: Collision Avoidance Information
System status
General

ID #: 397

Message: Side obstacle warning system failure

Source: ISO (proposed)

Notes:

File: LaneChange7F-7.jpg

ID #: 274

Message: Side obstacle warning system failure

Source: ISO (proposed)

Notes:

File: LaneChange7F-8.jpg

ID #: 45

Message: System failure

Source: SODS

Notes:

File: ex.jpg

ID #: 63

Message: System failure

Source: SODS

Notes:

File: System Malfunction.jpg

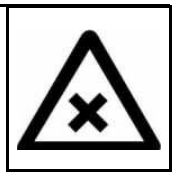
ID #: 78

Message: System failure

Source: http://members.arttoday.com/

Notes: warning03bw.jpg

File: x in triangle.jpg



Function: Collision Avoidance Information
System status
General

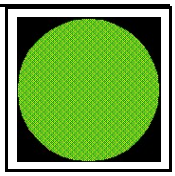
ID #: 300

Message: System on and functioning

Source: SODS

Notes:

File: circle.jpg



ID #: 36

Message: System on and functioning

Source: SODS

Notes:

File: System Check.jpg

ID #: 123

Message: System on and functioning

Source: SODS

Notes:

File: System OK.jpg

Function: Commercial Vehicle Operations Information
Augmented signage information
General

ID #: 1

Message: Allowable vehicle length on roadway

Source: Corel ®

Notes:

File: truck width.gif

Icon Details by Icon Type

Function: Commercial Vehicle Operations
Information
Augmented signage information
General

ID #: 6

Message: Allowable vehicle width on roadway

Source: Corel ®

Notes:

File: width.jpg

ID #: 350

Message: Hazardous cargo not allowed

Source: Corel ®

Notes:

File: no HC.jpg

ID #: 125

Message: Low clearance

Source: http://members.aol.com/rcmoeur/r12.html

Notes:

File: 13-6.jpg

ID #: 11

Message: Low clearance

Source: Corel ®

Notes:

File: 3.5.jpg

ID #: 379

Message: Weight limits

Source: http://members.aol.com/rcmoeur/d8.html

Notes: edited

File: 5.4.gif

Function: Commercial Vehicle Operations
Information
Augmented signage information
General

ID #: 396

Message: Weight limits

Source: http://members.aol.com/rcmoeur/d8.html

Notes:

File: weight.jpg

Function: Commercial Vehicle Operations
Information
Cargo and vehicle monitoring information
General

ID #: 328

Message: Problem in the trailer unit

Source: http://www.nzwwa.com/mirror/clipart/graphics/pictures/signs/index.html + http://members.aol.com/rcmoeur/r12.html

Notes: edited

File: truck.gif

Function: Commercial Vehicle Operations
Information
Trip planning
General

ID #: 175

Message: Diesel fuel location

Source: Corel ®

Notes:

File: diesel.jpg

Icon Details by Icon Type

Function: Commercial Vehicle Operations
Information
Trip planning
General

ID #: 141

Message: Truck stop

Source: http://members.aol.com/rcmoeur/rg.html + http://members.aol.com/rcmoeur/rm.html + http://members.aol.com/rcmoeur/d9.html

Notes: icons merged, edited

File: truck stop 1.gif

Function: General Navigation System Information
GPS status information
General

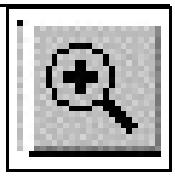
ID #: 84

Message: Magnify/minimize map view

Source: Adobe exchange 3.0

Notes:

File: magnify.jpg



ID #: 184

Message: Satellite signal strength

Source: Corel ®

Notes:

File: satellite 1.jpg

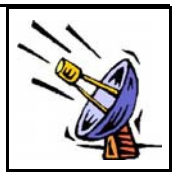
ID #: 330

Message: Satellite signal strength

Source: Corel ®

Notes:

File: satellite 2.jpg



Function: General Navigation System Information
GPS status information
General

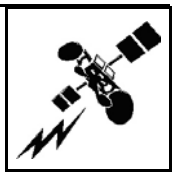
ID #: 60

Message: Satellite signal strength

Source: Corel ®

Notes:

File: satellite 3.jpg



Function: Motorist Services Information
Broadcast service/attractions
Airport

ID #: 335

Message: Airport

Source: MUTCD

Notes: edited

File: Airport.gif

ID #: 427

Message: Airport

Source: Industry

Notes:

File: poiAirports.gif

ID #: 156

Message: Airport information

Source: http://members.arttoday.com/

Notes: airportinfo01bw.jpg

File: Airport Info.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business general

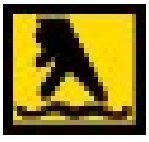
ID #: 81
Message: ATM
Source: Industry
Notes:
File: poiAtm.gif

ID #: 242
Message: Bank
Source: http://members.arttoday.com/
Notes: bank01bw.jpg
File: $building.jpg

ID #: 66
Message: Coffee shop
Source: http://www.geneseo.edu/icons/symbols/index.html
Notes:
File: coffee.jpg

ID #: 160
Message: Coffee shop
Source: Industry
Notes:
File: coffeeShops.gif

ID #: 109
Message: Directory (index of yellow pages)
Source: http://yp.yahoo.com
Notes:
File: 2 fingers.jpg



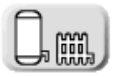
Function: Motorist Services Information
Broadcast service/attractions
Business general

ID #: 51
Message: Electric company
Source: Industry
Notes:
File: poiElectricCompany.gif

ID #: 380
Message: Electronics
Source: Industry
Notes:
File: poiElectronic.gif

ID #: 424
Message: Florist
Source: Industry
Notes:
File: poiFlorists.gif

ID #: 88
Message: Gas utility
Source: Industry
Notes:
File: poiGasUtility.gif



ID #: 343
Message: Ice cream shop
Source: www.iconbazaar.com
Notes:
File: icecream.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business general

ID #: 212

Message: Kennel

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Kennel.gif

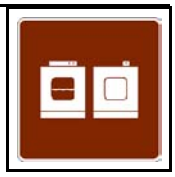
ID #: 388

Message: Laundry

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Washer & dryer.gif



ID #: 276

Message: Locker

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Key.gif

ID #: 334

Message: Lodging

Source: Industry

Notes:

File: poiLodging.gif

ID #: 377

Message: Real estate

Source: Industry

Notes:

File: poiRealEstate.gif

Function: Motorist Services Information
Broadcast service/attractions
Business general

ID #: 390

Message: Window glass

Source: Industry

Notes:

File: poiWindowGlass.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/auto

ID #: 368

Message: Auto glass

Source: Industry

Notes:

File: poiAutoGlass.gif

ID #: 250

Message: Auto parts

Source: Industry

Notes:

File: poiAutoParts.gif

ID #: 161

Message: Auto service

Source: Industry

Notes:

File: poiAutoService.gif

ID #: 135

Message: Auto tires

Source: Industry

Notes:

File: poiAutoTires.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business/auto

ID #: 25
Message: Auto transmission
Source: Industry
Notes:
File: poiAutoTransmission.gif

ID #: 404
Message: Car mechanic
Source: Teague
Notes:
File: wrench.jpg

ID #: 180
Message: Car rental agency
Source: http://membersarttoday.com/
Notes:
File: keycar.jpg

ID #: 82
Message: Car wash
Source: Industry
Notes:
File: poiCarWash.gif

ID #: 307
Message: Fuel
Source: Industry
Notes:
File: poiFuel.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/auto

ID #: 148
Message: Gas station ahead
Source: Teague
Notes:
File: gas3.jpg

ID #: 347
Message: Rental car
Source: Industry
Notes:
File: poiRentalCar.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/retail

ID #: 110
Message: Department store
Source: Industry
Notes:
File: poiDepartmentStores.gif

ID #: 70
Message: Furniture store
Source: Industry
Notes:
File: poiFurniture.gif

ID #: 361
Message: Grocery store
Source: http://members.arttoday.com/
Notes:
File: grocery.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business/retail

ID #: 72
Message: Grocery store
Source: http://members.arttoday.com/
Notes:
File: grocery2.jpg

ID #: 252
Message: Grocery store
Source: Industry
Notes:
File: poiGroceries.gif

ID #: 294
Message: Hardware store
Source: Industry
Notes:
File: poiHardware.gif

ID #: 288
Message: Home center
Source: Industry
Notes:
File: poiHomeCenter.gif

ID #: 187
Message: Office supply
Source: Industry
Notes:
File: poiOfficeSupply.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/retail

ID #: 193
Message: Photo equipment
Source: Industry
Notes:
File: poiPhotoEquip.gif

ID #: 339
Message: Software
Source: Industry
Notes:
File: poiSoftware.gif

ID #: 223
Message: Toy store
Source: Industry
Notes:
File: poiToyStore.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/service

ID #: 132
Message: Attorney
Source: Industry
Notes:
File: poiAttorneys.gif

ID #: 220
Message: Barber shop
Source: http://www.hardhatusa.com/cat162.html
Notes: ill0022, edited
File: barber.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business/service

ID #: 412
Message: Dry cleaning
Source: Industry
Notes:
File: poiDryCleaning.gif

ID #: 255
Message: Food
Source: Industry
Notes:
File: poiFood.gif

ID #: 165
Message: Hair salon
Source: Industry
Notes:
File: poiHairSalons.gif

ID #: 417
Message: House cleaning
Source: Industry
Notes:
File: poiHouseCleaning.gif

ID #: 302
Message: Lawn service
Source: Industry
Notes:
File: poiLawnService.gif

Function: Motorist Services Information
Broadcast service/attractions
Business/service

ID #: 71
Message: Pest service
Source: Industry
Notes:
File: poiPestService.gif

ID #: 370
Message: Photo copy
Source: Industry
Notes:
File: poiPhotoCopy.gif

ID #: 94
Message: Photo developing
Source: Industry
Notes:
File: poiPhotoDeveloping.gif

ID #: 333
Message: Plumbing/heating
Source: Industry
Notes:
File: poiPlumbHeat.gif

ID #: 217
Message: Pool service
Source: Industry
Notes:
File: poiPoolService.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Business/service

ID #: 236
Message: Roof service
Source: Industry
Notes:
File: poiRoofService.gif

ID #: 107
Message: Security
Source: Industry
Notes:
File: poiSecurity.gif

ID #: 150
Message: Tailor
Source: Industry
Notes:
File: poiTailors.gif

Function: Motorist Services Information
Broadcast service/attractions
Entertainment

ID #: 367
Message: Amphitheater
Source: MUTCD
Notes: edited
File: Theatre.gif

ID #: 80
Message: Arts and culture venue
Source: http://www.hardhatusa.com/cat161.html
Notes: gsl0035, edited
File: mask1.gif

Function: Motorist Services Information
Broadcast service/attractions
Entertainment

ID #: 111
Message: Casino
Source: Industry
Notes:
File: poiCasinos.gif

ID #: 154
Message: Casino
Source: Corel ®
Notes:
File: Roulette.jpg

ID #: 429
Message: Casino
Source: http://members.arttoday.com/
Notes: casino01bw.jpg
File: Slot Machine.jpg

ID #: 284
Message: Live music
Source: Industry
Notes:
File: poiLiveMusic.gif

ID #: 43
Message: Movie theater
Source: http://www.geneseo.edu/icons/symbols/index.html
Notes:
File: action.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Entertainment

ID #: 214

Message: Movie theater

Source: Industry

Notes:

File: poiCinema.gif

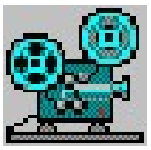
ID #: 101

Message: Movie theater

Source: http://www.geneseo.edu/icons/symbols/index.html

Notes:

File: Projecter 1.jpg



ID #: 346

Message: Movie theater

Source: Corel ®

Notes:

File: Projecter 2.jpg

ID #: 27

Message: Music venue

Source: http://www.geneseo.edu/icons/symbols/index.html

Notes:

File: Music note.jpg

ID #: 167

Message: Night life attraction

Source: http://hardhatusa.com/cat162.html

Notes: ill0015, edited

File: martini.gif

Function: Motorist Services Information
Broadcast service/attractions
Entertainment

ID #: 179

Message: Theater

Source: Corel ®

Notes:

File: Masks2.jpg

ID #: 137

Message: Theater

Source: http://www.artsci.wust1.edu/~dmreed/maskst.gif

Notes:

File: Masks3.jpg

ID #: 426

Message: Theater

Source: http://www.hardhatusa.com/cat161.html

Notes: gsl0036, edited

File: masks4.gif

ID #: 415

Message: Theater

Source: http://www.hardhatusa.com/cat161.html

Notes: gsl0033 [icon is both gsl0033 and gsl0034 combined], edited

File: masks5.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
General

ID #: 189

Message: Church

Source: Industry

Notes:

File: poiChurches.gif

ID #: 301

Message: College

Source: http://www.geneseo.edu/icons/symbols/two.html

Notes:

File: Grad Cap.jpg

ID #: 130

Message: Elevator

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Elevator.gif

ID #: 86

Message: General winter recreation

Source: MUTCD

Notes: edited

File: Snowflake.gif

ID #: 164

Message: Information

Source: Corel ®

Notes:

File: Info.jpg

Function: Motorist Services Information
Broadcast service/attractions
General

ID #: 362

Message: Landmark information

Source: Corel ®

Notes:

File: Point out.jpg

ID #: 425

Message: Library

Source: MUTCD

Notes: edited

File: Read.gif

ID #: 62

Message: Mail box

Source: Industry

Notes:

File: poiMailBox.gif

ID #: 237

Message: Point of interest

Source: Industry

Notes:

File: poi.gif

ID #: 395

Message: Rest area ahead

Source: MUTCD

Notes: edited

File: RestAreaAhead.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
General

ID #: 338

Message: Restrooms

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Men.gif

ID #: 389

Message: Restrooms

Source: MUTCD

Notes: edited

File: Restrooms.gif

ID #: 409

Message: Restrooms

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Women.gif

ID #: 170

Message: School

Source: http://members.arttoday.com/

Notes: crosswalk01w.jpg

File: Pedestrians.jpg

ID #: 234

Message: Zoo

Source: http://www.geneseo.edu/icons/symbols/index.html

Notes:

File: Zoo 1.jpg

Function: Motorist Services Information
Broadcast service/attractions
General

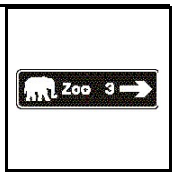
ID #: 314

Message: Zoo

Source: http://www.highways.gow.uk/educate/educate.htm

Notes:

File: Zoo 2.jpg



Function: Motorist Services Information
Broadcast service/attractions
Government

ID #: 77

Message: City hall/government building

Source: Corel ®

Notes:

File: Political Building.jpg

ID #: 290

Message: Courthouse

Source: http://www.hardhatusa.com/cat161.html

Notes: gsl0042, edited

File: gavel.gif

ID #: 420

Message: Courthouse

Source: Corel ®

Notes:

File: Scales.jpg

ID #: 152

Message: Post office

Source: Corel ®

Notes:

File: Mail 1.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Government

ID #: 155
Message: Post office
Source: Corel ®
Notes:
File: Mail 2.jpg

ID #: 185
Message: Post office
Source: Industry
Notes:
File: poiPostOffices.gif

Function: Motorist Services Information
Broadcast service/attractions
Internet/Phone

ID #: 418
Message: Phone
Source: Clickart
Notes:
File: Phone1.jpg

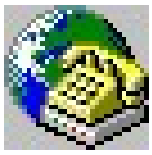
ID #: 241
Message: Phone
Source: Clickart
Notes:
File: Phone2.jpg

ID #: 26
Message: Phone
Source: Clickart
Notes:
File: Phone3.jpg

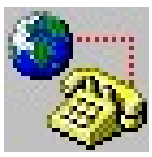
Function: Motorist Services Information
Broadcast service/attractions
Internet/Phone

ID #: 292
Message: Phone
Source: MUTCD
Notes: edited
File: Phone4.gif

ID #: 316
Message: Phone, internet connection
Source: http://www.geneseo.edu/icons/symbols/two.html
Notes:
File: connect.jpg



ID #: 376
Message: Phone, internet connection
Source: http://www.geneseo.edu/icons/symbols/two.html
Notes:
File: connected.jpg



ID #: 29
Message: Telephone
Source: Industry
Notes:
File: telephone.gif

Function: Motorist Services Information
Broadcast service/attractions
Medical

ID #: 413
Message: Hospital
Source: http://www.dps.state.ak.us/dmv/DLMANUAL/signs.htm
Notes:
File: hospital 1.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Medical

ID #: 352

Message: Hospital

Source: http://members.arttoday.com/

Notes: hospital01bw.jpg

File: Hospital 2.jpg

ID #: 337

Message: Hospital

Source: http://members.aol.com/rcmoeur/rm.html

Notes:

File: Hospital Right.jpg

ID #: 272

Message: Hospital

Source: Corel ®

Notes:

File: Med Assist 2.jpg

ID #: 310

Message: Medical assistance

Source: www.iconbazaar.com

Notes:

File: Med Assist 1.jpg

ID #: 54

Message: Medical assistance

Source: Industry

Notes:

File: poiHospital.gif

Function: Motorist Services Information
Broadcast service/attractions
Medical

ID #: 430

Message: Pharmacy

Source: Industry

Notes:

File: poiPharmacies.gif

ID #: 406

Message: Physician

Source: Industry

Notes:

File: poiPhysicians.gif

ID #: 263

Message: Veternarian

Source: Industry

Notes:

File: poiVeternarian.gif

Function: Motorist Services Information
Broadcast service/attractions
Parking

ID #: 12

Message: Park and ride

Source: http://members.aol.com/rcmoeur/d4.html

Notes:

File: park&ride.jpg

ID #: 323

Message: Parking

Source: Industry

Notes:

File: poiParking.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Parking

ID #: 411
Message: Parking lot
Source: Corel ®
Notes:
File: Parking.jpg

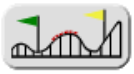
ID #: 15
Message: Type of parking facility
Source: Corel ®
Notes:
File: wheelchair.jpg

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 28
Message: All-terrain vehicle trail
Source: http://members.aol.com/rcmoeur/rl.html
Notes:
File: 4 wheeler.gif

ID #: 240
Message: Amusement park
Source: Corel ®
Notes:
File: Amusement park.jpg

ID #: 157
Message: Amusement park
Source: Industry
Notes:
File: poiAmusement.gif



Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 200
Message: Bicycle trail
Source: http://members.arttoday.com/
Notes: bicycle01bw.jpg
File: bike 1.jpg

ID #: 41
Message: Bicycle trail
Source: http://members.arttoday.com/
Notes: bicycle02bw.jpg
File: bike 2.jpg

ID #: 90
Message: Boat launching
Source: http://members.arttoday.com/
Notes: boatlanding01bw.jpg
File: boat 5.jpg

ID #: 39
Message: Campground
Source: Industry
Notes:
File: poiCampround.gif

ID #: 131
Message: Camping
Source: MUTCD
Notes: edited
File: Camping 2.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 47

Message: Canoeing

Source: MUTCD

Notes: edited

File: boat 2.gif

ID #: 342

Message: Climbing

Source: http://members.aol.com/rcmoeur/rl.html

Notes:

File: Rock Climbing.gif

ID #: 13

Message: Cross-country skiing

Source: http://members.aol.com/rcmoeur/rs.html

Notes:

File: ski 2.gif

ID #: 360

Message: Diving

Source: http://members.arttoday.com/

Notes:

File: diver.jpg

ID #: 7

Message: Downhill skiing

Source: http://members.aol.com/rcmoeur/rs.html

Notes:

File: ski 3.gif

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 327

Message: Fishing

Source: http://members.arttoday.com/

Notes:

File: fish.jpg

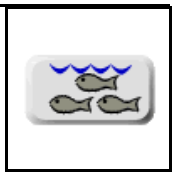
ID #: 198

Message: Fishing lake

Source: Industry

Notes:

File: poiFishingLakes.gif



ID #: 391

Message: Golf course

Source: Corel ®

Notes:

File: Golf 1.jpg

ID #: 229

Message: Golf course

Source: Corel ®

Notes:

File: Golf 2.jpg

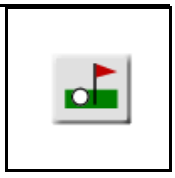
ID #: 277

Message: Golfing

Source: Industry

Notes:

File: poiGolfing.gif



Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 102

Message: Hiking

Source: http://members.aol.com/rcmoeur/rl.html

Notes:

File: Hiking.gif

ID #: 174

Message: Horse trail

Source: http://members.aol.com/rcmoeur/rl.html

Notes:

File: rider.gif

ID #: 423

Message: Hunting

Source: http://members.arttoday.com/

Notes:

File: Deer 1.jpg

ID #: 190

Message: Hunting

Source: http://members.aol.com/rcmoeur/rl.html

Notes:

File: rifle.jpg

ID #: 50

Message: Ice skating

Source: MUTCD

Notes: edited

File: skate.gif

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 56

Message: Kayaking

Source: http://members.arttoday.com/

Notes: kayak01bw.jpg

File: boat 3.jpg

ID #: 305

Message: Marina

Source: http://members.aol.com/rcmoeur/rw.html

Notes:

File: anchor.gif

ID #: 222

Message: Motor boating

Source: http://members.aol.com/rcmoeur/rw.html

Notes:

File: boat 1.gif

ID #: 168

Message: Motor boating

Source: http://members.aol.com/rcmoeur/rw.html

Notes:

File: boat 4.gif

ID #: 344

Message: Off-road trail

Source: http://members.arttoday.com/

Notes: atv02bw.jpg

File: jeep.jpg

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 428
Message: Park
Source: Industry
Notes:
File: poiParks.gif

ID #: 408
Message: Picnic area
Source: MUTCD
Notes: edited
File: Picnic.gif

ID #: 213
Message: Playground
Source: MUTCD
Notes: edited
File: teeter totter.gif

ID #: 142
Message: Recreation center
Source: Industry
Notes:
File: poiRecCenters.gif

ID #: 89
Message: Rock collecting
Source: http://members.aol.com/rcmoeur/rl.html
Notes:
File: chisel.gif

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 233
Message: Row boating
Source: Teague
Notes:
File: boat 6.jpg

ID #: 99
Message: RV park
Source: http://members.arttoday.com/
Notes: camper01bw.jpg
File: Camper.jpg

ID #: 311
Message: RV park
Source: http://members.arttoday.com/
Notes: rv04bw.jpg
File: Trailer.jpg

ID #: 112
Message: Sail-boating
Source: Teague
Notes:
File: boat 7.jpg

ID #: 283
Message: Scuba diving
Source: http://members.aol.com/rcmoeur/rw.html
Notes:
File: scuba.gif

Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 22

Message: Shower

Source: http://members.aol.com/rcmoeur/ra.html

Notes:

File: Shower.gif

ID #: 147

Message: Snowmobiling

Source: http://members.arttoday.com/

Notes: snowmobiling04bw.jpg

File: snomobile.jpg

ID #: 221

Message: Sport stadium

Source: http://kazoobiz.com/marketplace/images/stadium.gif

Notes: edited

File: Stadium.gif

ID #: 115

Message: Stable

Source: http://members.aol.com/rcmoeur/rl.html

Notes:

File: horse.gif

ID #: 226

Message: Surfing

Source: http://members.aol.com/rcmoeur/rw.html

Notes:

File: surf.gif

Function: Motorist Services Information
Broadcast service/attractions
Recreation

ID #: 67

Message: Swimming

Source: MUTCD

Notes: edited

File: swim.gif

ID #: 93

Message: Tent/trailer park

Source: http://members.arttoday.com/

Notes: rvtent01c2.jpg, edited

File: Camping.gif

ID #: 329

Message: Tourist attraction

Source: Industry

Notes:

File: poiTouristAttractions.gif

ID #: 134

Message: Water sports

Source: Teague

Notes:

File: watersports.jpg

ID #: 10

Message: Water-skiing

Source: http://members.aol.com/rcmoeur/rw.html

Notes:

File: ski 1.gif

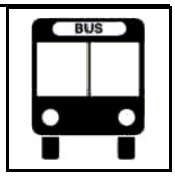
Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Recreation

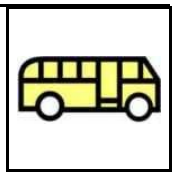
ID #: 358
Message: Zoo
Source: Industry
Notes:
File: poiZoos.gif

Function: Motorist Services Information
Broadcast service/attractions
Transit

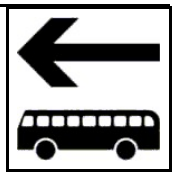
ID #: 340
Message: Bus station
Source: http://members.arttoday.com/
Notes: bus08bw.jpg
File: Bus 3.jpg



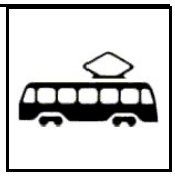
ID #: 46
Message: Bus station
Source: http://members.arttoday.com/
Notes: schoolbus02c.jpg
File: bus 4.jpg



ID #: 61
Message: Bus station
Source: http://members.arttoday.com/
Notes: bus05bw.jpg
File: Bus Left.jpg

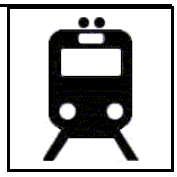


ID #: 16
Message: Commuter rail station
Source: http://members.arttoday.com/
Notes: subway02bw.jpg
File: Bus 2.jpg

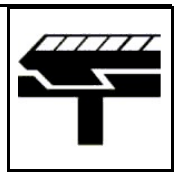


Function: Motorist Services Information
Broadcast service/attractions
Transit

ID #: 83
Message: Commuter rail station
Source: http://members.arttoday.com/
Notes: subway01bw.jpg, edited
File: Train 1.gif

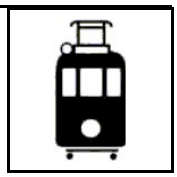


ID #: 100
Message: Commuter rail station
Source: http://members.arttoday.com/
Notes: monorail01bw.jpg
File: Train 2.jpg

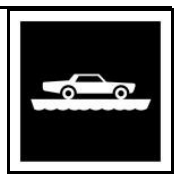


ID #: 387
Message: Commuter rail station
Source: http://members.arttoday.com/
Notes: subway03bw.jpg
File: Train 3.jpg

ID #: 49
Message: Commuter rail station
Source: http://members.arttoday.com/
Notes: trolley01bw.jpg
File: Train 4.jpg



ID #: 231
Message: Ferry terminal
Source: http://members.arttoday.com/
Notes: ferry02bw.jpg
File: Carferry1.jpg



Icon Details by Icon Type

Function: Motorist Services Information
Broadcast service/attractions
Transit

ID #: 163
Message: Ferry terminal
Source: http://members.arttoday.com/
Notes: ferry05bw.jpg
File: Carferry2.jpg

ID #: 151
Message: Imminent collision warning
Source: Corel ®
Notes:
File: Train 6.gif

ID #: 192
Message: Train station
Source: Corel ®
Notes:
File: Train 5.jpg

Function: Motorist Services Information
Destination coordination
General

ID #: 219
Message: Rest area exit
Source: Corel ®
Notes:
File: RA.jpg

Function: Motorist Services Information
Email, messaging
General

ID #: 400
Message: Address book
Source: Industry
Notes:
File: addressbook.gif

ID #: 282
Message: Address book
Source: Industry
Notes:
File: addressbookAll.gif

ID #: 203
Message: Address book - business
Source: Industry
Notes:
File: addressbookBusiness.gif

ID #: 204
Message: Address book - family
Source: Industry
Notes:
File: addressbookFamily.gif

ID #: 166
Message: Address book - friends
Source: Industry
Notes:
File: addressbookFriends.gif

Icon Details by Icon Type

Function: Motorist Services Information
Email, messaging
General

ID #: 405
Message: Users
Source: Industry
Notes:
File: users.gif

Function: Motorist Services Information
Entertainment
General

ID #: 319
Message: CD player
Source: Industry
Notes:
File: cdPlayer.gif

ID #: 257
Message: Entertainment - sports
Source: Industry
Notes:
File: genreSports.gif

ID #: 384
Message: Entertainment - talk
Source: Industry
Notes:
File: genreTalk.gif

ID #: 422
Message: Entertainment - TV
Source: Industry
Notes:
File: genreTV.gif

Function: Motorist Services Information
Entertainment
General

ID #: 128
Message: Favorites
Source: Industry
Notes:
File: favorites.gif

ID #: 398
Message: Music genre
Source: Industry
Notes:
File: genre.gif

ID #: 365
Message: Music genre
Source: Industry
Notes:
File: genreOther.gif

ID #: 394
Message: Music genre - alternative
Source: Industry
Notes:
File: genreAlternative.gif

ID #: 121
Message: Music genre - classic rock
Source: Industry
Notes:
File: genreClassicRock.gif

Icon Details by Icon Type

Function: Motorist Services Information
Entertainment
General

ID #: 127
Message: Music genre - classical
Source: Industry
Notes:
File: genreClassical.gif

ID #: 392
Message: Music genre - country
Source: Industry
Notes:
File: genreCountry.gif

ID #: 270
Message: Music genre - easy listening
Source: Industry
Notes:
File: genreEasyListening.gif

ID #: 19
Message: Music genre - latin
Source: Industry
Notes:
File: genreLatin.gif

ID #: 34
Message: Music genre - oldies
Source: Industry
Notes:
File: genreOldies.gif

Function: Motorist Services Information
Entertainment
General

ID #: 419
Message: Music genre - R&B, rap
Source: Industry
Notes:
File: genreR&BRap.gif

ID #: 254
Message: Music genre - rock
Source: Industry
Notes:
File: genreRock.gif

ID #: 140
Message: Music genre - top 40
Source: Industry
Notes:
File: genreTop40.gif

ID #: 79
Message: News
Source: Industry
Notes:
File: genreNews.gif

ID #: 17
Message: Radio
Source: Industry
Notes:
File: radio.gif

Icon Details by Icon Type

Function: Motorist Services Information
Entertainment
General

ID #: 253
Message: Radio - AM
Source: Industry
Notes:
File: radioAM.gif

ID #: 181
Message: Video rental
Source: Industry
Notes:
File: poiVideoRent.gif

Function: Motorist Services Information
Internet access
General

ID #: 144
Message: Stocks
Source: Industry
Notes:
File: stocks.gif

ID #: 205
Message: Stocks - DOW
Source: Industry
Notes:
File: stocksDOW.gif

ID #: 91
Message: Stocks - NASDAQ
Source: Industry
Notes:
File: stocksNASDAQ.gif

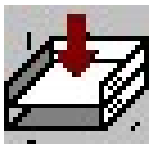
Function: Motorist Services Information
Internet access
General

ID #: 38
Message: Stocks - Russell 2000
Source: Industry
Notes:
File: stocksR2000.gif

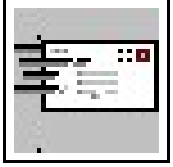
ID #: 232
Message: Stocks - S&P 500
Source: Industry
Notes:
File: stocksSP500.gif

Function: Motorist Services Information
Message transfer
General

ID #: 52
Message: Incoming message
Source: http://www.awesomeicons.com
Notes:
File: files.jpg



ID #: 381
Message: Message sent/send message
Source: http://www.awesomeicons.com
Notes:
File: flying letter.jpg



Icon Details by Icon Type

Function: Motorist Services Information
Message transfer
General

ID #: 215

Message: Problem with sent e-mail

Source: http://www.awesomeicons.com

Notes: edited

File: lightning letter.gif

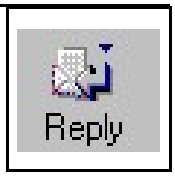
ID #: 201

Message: Reply to a message

Source: Netscape Communicator 4.04 ®

Notes:

File: reply.jpg



ID #: 124

Message: Retrieve message

Source: Netscape Communicator 4.04 ®

Notes:

File: get msg.jpg

ID #: 58

Message: Save message

Source: Corel ®

Notes:

File: file.jpg

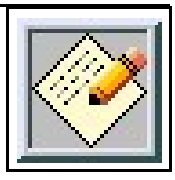
ID #: 243

Message: Write message

Source: http://www.cit.gu.edu.au/images/Images.html

Notes:

File: pencil-paper.jpg



Function: Routing and Navigation
Route guidance
Emergency vehicles

ID #: 245

Message: Approaching emergency vehicle

Source: Teague

Notes:

File: Emergency veh1.jpg

ID #: 118

Message: Approaching emergency vehicle

Source: Teague

Notes:

File: Emergency veh2.jpg

ID #: 202

Message: Approaching emergency vehicle

Source: Teague

Notes:

File: fire.jpg

ID #: 410

Message: Approaching emergency vehicle

Source: Teague

Notes:

File: red cross vehicle.jpg

Icon Details by Icon Type

Function: **Routing and Navigation**
Route guidance
General

ID #: 291

Message: Route home

Source: ISO (proposed)

Notes:

File: RouteGuidance1D-1.jpg

ID #: 3

Message: Vehicle's current position

Source: Corel ®

Notes:

File: Star.jpg

ID #: 133

Message: Vehicle's current position

Source: 5www.etak.com/skymap/index/html

Notes: edited

File: You're here.gif

Function: **Routing and Navigation**
Route guidance
Road closures

ID #: 239

Message: Construction ahead - alternate route

Source: Teague

Notes:

File: Exit for construction.jpg

ID #: 248

Message: Crash ahead - alternate route

Source: Teague

Notes:

File: lanes blocked 1.jpg

Function: **Routing and Navigation**
Route guidance
Road closures

ID #: 178

Message: Hazardous spill ahead - alternate route

Source: Teague

Notes:

File: lanes blocked 2.jpg

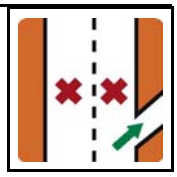
ID #: 224

Message: Road closed ahead - alternate route

Source: Teague

Notes:

File: lanes blocked 3.jpg



Function: **Routing and Navigation**
Route navigation
General

ID #: 403

Message: Advisory exit speed sign

Source: http://members.aol.com/rcmoeur/w13.html

Notes:

File: Exit Speed.jpg

ID #: 120

Message: Exit

Source: http://members.aol.com/rcmoeur/e.html

Notes:

File: Exit.jpg

Icon Details by Icon Type

Function: Routing and Navigation
Route navigation
General

ID #: 188

Message: Lane suggestion for next turn

Source: Corel ®

Notes:

File: Right lane entering.jpg

ID #: 32

Message: Recent destinations

Source: Industry

Notes:

File: recentDestinations.gif

ID #: 145

Message: Turn sign

Source: Corel ®

Notes:

File: Sharp right turn.gif

Function: Routing and Navigation
Travel coordination and planning
General

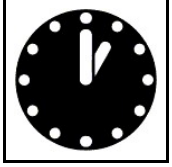
ID #: 267

Message: Start time required to catch other mode of transport

Source: http://members.arttoday.com/

Notes: time01bw.jpg

File: clock1.jpg



ID #: 92

Message: Start time required to catch other mode of transport

Source: http://members.arttoday.com/

Notes: time02bw.jpg

File: clock2.jpg

Function: Routing and Navigation
Travel coordination and planning
General

ID #: 113

Message: Start time required to catch other mode of transport

Source: http://members.arttoday.com/

Notes: start01c.jpg

File: racecars.jpg

ID #: 247

Message: Total time to complete travel

Source: Drawn

Notes:

File: All segments.jpg

ID #: 278

Message: Travel time for one segment

Source: Drawn

Notes:

File: 1segment.jpg

Function: Routing and Navigation
Trip planning
Attractions

ID #: 375

Message: Landmarks or topographical features

Source: http://members.arttoday.com/

Notes: landmark03c.jpg

File: pyramids.jpg

Icon Details by Icon Type

Function: Routing and Navigation
Trip planning
Attractions

ID #: 153

Message: Landmarks or topographical features

Source: http://members.arttoday.com/

Notes: landmark04c.jpg

File: Statue Lib.jpg

ID #: 279

Message: Landmarks or topographical features

Source: http://members.arttoday.com/

Notes: landmark05c.jpg

File: WhiteHouse.jpg

ID #: 182

Message: Locations of state and national parks

Source: MUTCD

Notes: edited

File: Natl park.gif

Function: Routing and Navigation
Trip planning
Costs

ID #: 9

Message: Number of tolls and cost of each toll per segment

Source: http://www.ettm.com, http://members.arttoday.com/,

Notes:

File: Toll.jpg

Function: Routing and Navigation
Trip planning
Costs

ID #: 194

Message: Price range of food at restaurants

Source: Teague

Notes:

File: Food Price.jpg

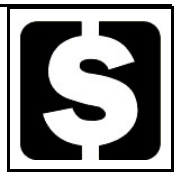
ID #: 359

Message: Total trip cost

Source: http://members.arttoday.com/

Notes: dollar02bw.jpg

File: money1.jpg



ID #: 269

Message: Total trip cost

Source: http://members.arttoday.com/

Notes: dollar03bw.jpg

File: money2.jpg

ID #: 364

Message: Total trip cost

Source: http://members.arttoday.com/

Notes: dollar04bw.jpg

File: money3.jpg

Function: Routing and Navigation
Trip planning
General

ID #: 308

Message: Crime warning

Source: Corel ®

Notes: edited

File: Gun.jpg

Icon Details by Icon Type

Function: Routing and Navigation
Trip planning
General

ID #: 369

Message: Fastest route available

Source: Rand McNally 1996 edition

Notes:

File: quicktrip.jpg

ID #: 230

Message: Length of wait

Source: http://members.arttoday.com/

Notes: time03bw.jpg

File: Sit time.jpg

ID #: 273

Message: Most scenic route

Source: Rand McNally 1996 edition

Notes:

File: scenery.jpg

ID #: 48

Message: Number of traffic lights/stops of route options

Source: Corel ®

Notes: suggest combining icon with digital display below

File: Stoplight.jpg

ID #: 298

Message: Road end/ bridge out

Source: Corel ®

Notes:

File: roadend.jpg

Function: Routing and Navigation
Trip planning
General

ID #: 225

Message: Route avoiding tollways

Source: http://www.thruway.state.ny.us/+editing and http:/www.dhp.nl/traffic/info-e.html

Notes:

File: No Toll.jpg

ID #: 297

Message: States, regions, communities, and districts along the route

Source: http://members.arttoday.com/

Notes: unitedstates03bw.jpg

File: map.jpg

ID #: 325

Message: Transit schedules in areas along route

Source: http://members.arttoday.com/

Notes: transit03bw.jpg

File: Bus 1.jpg

ID #: 21

Message: Type of roads on route

Source: http://members.aol.com/rcmoeur/w8.html

Notes: Indicates transition from concrete to gravel, edited

File: gravel.jpg

Icon Details by Icon Type

Function: Routing and Navigation
Trip planning
General

ID #: 353

Message: Type of roads on route

Source: http://members.arttoday.com/

Notes: tunnel01bw.jpg

File: tunnel.jpg

Function: Routing and Navigation
Trip planning
Lodging

ID #: 382

Message: Lodging

Source: Teague

Notes:

File: Lodging.jpg

ID #: 76

Message: No vacancy

Source: http://members.arttoday.com/ + editing

Notes: lodging 04bw.jpg

File: No vacancy X.jpg

ID #: 136

Message: No vacancy

Source: Corel ®

Notes: No Vacancy

File: No vacancy.jpg

ID #: 356

Message: Price of lodging

Source: http://members.aol.com/rcmoeur/rm.html + editing

Notes: Superimposed text when motels are full, edited

File: No vacancy$.gif

Function: Routing and Navigation
Trip planning
Lodging

ID #: 35

Message: Price of lodging

Source: Teague

Notes:

File: Price lodging.jpg

ID #: 320

Message: Restaurant/food ahead

Source: Corel ®

Notes:

File: Food plate.jpg

ID #: 218

Message: Restaurant/food ahead

Source: http://members.aol.com/rcmoeur/rm.html

Notes: edited

File: Food.gif

ID #: 177

Message: Restaurant/food ahead

Source: Teague

Notes:

File: utensils.jpg

ID #: 196

Message: Vacancy

Source: Corel ®

Notes: Vacancy

File: vacancy.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Airbag status/information
General

ID #: 286

Message: Airbag

Source: ISO

Notes:

File: AirBagStatus-Information4G-4.jpg

ID #: 30

Message: Driver airbag off or not available

Source: ISO

Notes:

File: AirBagStatus-Information4G-5.jpg

ID #: 259

Message: Passenger airbag

Source: ISO

Notes:

File: AirBagStatus-Information4G-1.jpg

ID #: 280

Message: Passenger airbag off or not available

Source: ISO

Notes:

File: AirBagStatus-Information4G-2.jpg

ID #: 64

Message: Side impact airbag

Source: ISO

Notes:

File: AirBagStatus-Information4G-3.jpg

Function: Safety and Warning Information
Automatic/manual aid request
General

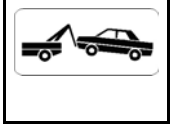
ID #: 348

Message: Inform driver that aid had been requested

Source: Corel ®

Notes:

File: InformDriverAidRequested.jpg



Function: Safety and Warning Information
Immediate hazard warning
General

ID #: 149

Message: Emergency vehicle stopped ahead

Source: Teague

Notes:

File: right lane x.jpg

Function: Safety and Warning Information
Parking aids
General

ID #: 33

Message: Parking aid

Source: ISO

Notes:

File: ParkingAids4F-5.jpg

ID #: 103

Message: Parking aid off or not available

Source: ISO (proposed)

Notes:

File: ParkingAids4F-1.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Parking aids
General

ID #: 266

Message: Parking aid off or not available

Source: ISO (proposed)

Notes:

File: ParkingAids4F-2.jpg

ID #: 171

Message: Parking aid system failure

Source: ISO (proposed)

Notes:

File: ParkingAids4F-3.jpg

ID #: 249

Message: Parking aid system failure

Source: ISO (proposed)

Notes:

File: ParkingAids4F-4.jpg

ID #: 138

Message: Reverse/ backing aid

Source: ISO (proposed)

Notes:

File: ParkingAids4F-6.jpg

ID #: 315

Message: Reverse/ backing aid failure

Source: ISO (proposed)

Notes:

File: ParkingAids4F-7.jpg

Function: Safety and Warning Information
Parking aids
General

ID #: 159

Message: Reverse/ backing aid failure

Source: ISO (proposed)

Notes:

File: ParkingAids4F-8.jpg

Function: Safety and Warning Information
Road condition information
General

ID #: 261

Message: Accident ahead

Source: Teague

Notes:

File: right lane x 3.jpg

ID #: 357

Message: Fallen rock ahead

Source: http://members.arttoday.com/

Notes: fallingrock01bw.jpg, edited

File: rocks.gif

ID #: 5

Message: Icy roads ahead

Source: http://members.arttoday.com/

Notes: slippery02bw.jpg

File: slippery.jpg

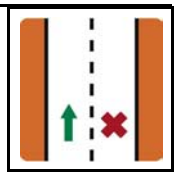
ID #: 197

Message: Lanes blocked ahead

Source: Teague

Notes:

File: right lane x 4.jpg



Icon Details by Icon Type

Function: Safety and Warning Information
Road condition information
General

ID #: 122

Message: Low shoulder

Source: Teague

Notes:

File: slow 3.jpg

ID #: 191

Message: Road closed

Source: Industry

Notes:

File: trafficConstruction.gif

ID #: 312

Message: Road closed ahead

Source: http://members.arttoday.com/

Notes: roadclosed01bw.jpg

File: Road Closed.jpg

ID #: 227

Message: Road work/construction ahead

Source: Teague

Notes:

File: right lane x 2.jpg

ID #: 322

Message: Road work/construction ahead

Source: Teague

Notes:

File: slow 1.jpg

Function: Safety and Warning Information
Road condition information
General

ID #: 98

Message: Traffic congestion

Source: Campbell, J. L., Carney, C., & Kantowitz, B. H. (1998). Human factors design guidelines for advanced traveler information systems (ATIS) and commercial vehicle operations (CVO) (FHWA-RD-98-057). Washington, DC: Federal Highway Administration.

Notes:

File: traffic.jpg

ID #: 40

Message: Traffic congestion

Source: Industry

Notes:

File: trafficCongestion.gif

ID #: 285

Message: Traffic event

Source: Industry

Notes:

File: trafficEvent.gif

ID #: 186

Message: Traffic/congestion ahead

Source: Corel ®

Notes:

File: 3 cars.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Road condition information
General

ID #: 295

Message: Uneven road ahead

Source: Teague

Notes:

File: slow 2.jpg

Function: Safety and Warning Information
Vehicle condition monitoring
Information

ID #: 75

Message: Provide more detailed information at the drivers request

Source: Corel ®

Notes:

File: help 2.jpg

ID #: 331

Message: Provide more detailed information at the drivers request

Source: Corel ®

Notes:

File: help 3.jpg

Function: Safety and Warning Information
Vehicle condition monitoring
Mechanical

ID #: 374

Message: Inform driver of current problem

Source: Teague

Notes:

File: wrench 1.jpg

Function: Safety and Warning Information
Vehicle condition monitoring
Mechanical

ID #: 108

Message: Low oil pressure

Source: Corel ®

Notes:

File: lamp.jpg

Function: Safety and Warning Information
Vehicle condition monitoring
Tires

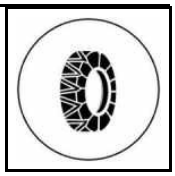
ID #: 313

Message: Chains required/ recommended

Source: http://members.arttoday.com/

Notes: tire01bw.jpg

File: tire 3.jpg



ID #: 321

Message: Low tire pressure

Source: Teague

Notes:

File: tire 2.jpg

ID #: 258

Message: Low tire pressure

Source: Campbell, J. L., Carney, C., & Kantowitz, B. H. (1998). Human factors design guidelines for advanced traveler information systems (ATIS) and commercial vehicle operations (CVO) (FHWA-RD-98-057). Washington, DC: Federal Highway Administration.

Notes:

File: tire.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Vehicle condition monitoring
Tires

ID #: 23

Message: Tire failure

Source: ISO

Notes:

File: VehicleCondition4E-1.jpg

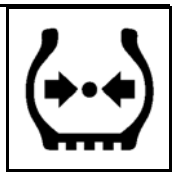
ID #: 304

Message: Tire pressure

Source: ISO

Notes:

File: VehicleCondition4E-2.jpg



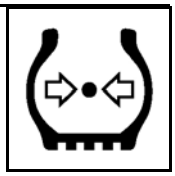
ID #: 265

Message: Tire pressure

Source: ISO

Notes:

File: VehicleCondition4E-3.jpg



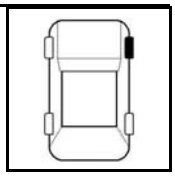
ID #: 158

Message: Tire pressure warning

Source: NHTSA (tested)

Notes: edited

File: icon4_car2.gif



ID #: 355

Message: Tire pressure warning

Source: NHTSA (tested)

Notes:

File: Wheel2_Flat1 inverted.jpg

Function: Safety and Warning Information
Vehicle condition monitoring
Tires

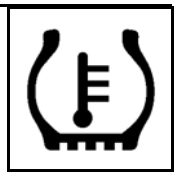
ID #: 402

Message: Tire temperature

Source: ISO

Notes:

File: VehicleCondition4E-4.jpg



Function: Safety and Warning Information
Weather information
General

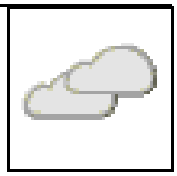
ID #: 97

Message: Cloudy

Source: Industry

Notes:

File: weatherCloudy.gif



ID #: 211

Message: Cloudy conditions

Source: http://www.intellicast.com/

Notes:

File: cloud 2.jpg

ID #: 289

Message: Cloudy conditions

Source: http://members.arttoday.com/

Notes: cloudy03bw.jpg

File: cloud 3.jpg

ID #: 117

Message: General weather forecast for a specific area

Source: http://www.wunderground.com/US/IA/Iowa_City.html

Notes:

File: Question Mark.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Weather information
General

ID #: 208

Message: Mostly cloudy

Source: http://www.freep.com/news/weather/index.htm

Notes:

File: sun 1.jpg

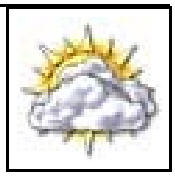
ID #: 336

Message: Mostly cloudy

Source: http://weather.com/

Notes:

File: sun 2.jpg



ID #: 401

Message: Mostly cloudy

Source: http://www.intellicast.com/

Notes:

File: sun 3.jpg

ID #: 143

Message: Mostly cloudy

Source: http://www.accuweather.com/

Notes:

File: sun 4.jpg

ID #: 146

Message: Mostly cloudy

Source: Industry

Notes:

File: weather.gif

Function: Safety and Warning Information
Weather information
General

ID #: 251

Message: Mostly cloudy

Source: Industry

Notes:

File: weatherMostlycloudy.gif

ID #: 126

Message: Partly cloudy

Source: http://members.arttoday.com/

Notes: partlycloudy01c.jpg

File: cloud 4.jpg

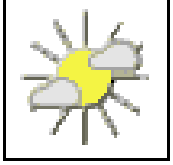
ID #: 324

Message: Partly cloudy

Source: Industry

Notes:

File: weatherPartlycloudy.gif



ID #: 95

Message: Rain

Source: http://www.weather.com/

Notes:

File: rain 1.jpg

ID #: 238

Message: Rain

Source: http://www.intellicast.com/

Notes:

File: rain 2.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Weather information
General

ID #: 207
Message: Rain
Source: http://www.weather24.com/
Notes:
File: rain 3.jpg

ID #: 73
Message: Rain
Source: http://www.accuweather.com/
Notes:
File: rain 4.jpg

ID #: 169
Message: Rain
Source: http://www.weather.com/
Notes: scatteredshowers01c.gif
File: rain 5.jpg

ID #: 318
Message: Rain
Source: http://members.arttoday.com/
Notes: rain01c.jpg
File: rain 6.jpg

ID #: 20
Message: Rain
Source: http://members.arttoday.com/
Notes: rain02bw.jpg
File: rain 7.jpg

Function: Safety and Warning Information
Weather information
General

ID #: 309
Message: Rain and snow
Source: Industry
Notes:
File: weatherRainsnow.gif

ID #: 2
Message: Rain/ lightning
Source: Industry
Notes:
File: weatherThunderstorm.gif

ID #: 371
Message: Rain/lighting
Source: http://members.arttoday.com/
Notes: thunderstorm01bw.jpg
File: lightning.jpg

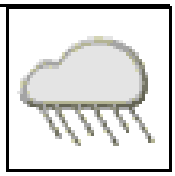
ID #: 173
Message: Rain/lighting
Source: http://www.weather24.com/
Notes:
File: rain 8.jpg

ID #: 57
Message: Rain/lighting
Source: http://www.weather.com
Notes: t-storms01c.gif
File: rain 9.jpg

Icon Details by Icon Type

Function: Safety and Warning Information
Weather information
General

ID #: 383
Message: Rainy
Source: Industry
Notes:
File: weatherRainy.gif

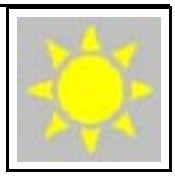


ID #: 105
Message: Snow
Source: http://www.intellicast.com/
Notes:
File: cloud 1.jpg

ID #: 209
Message: Snow
Source: MUTCD
Notes: edited
File: snow.gif

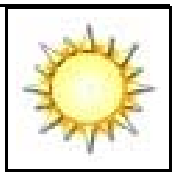
ID #: 287
Message: Snow
Source: Industry
Notes:
File: weatherSnow.gif

ID #: 244
Message: Sunny
Source: http://www.geneseo.edu/icons/symbols/index.html
Notes:
File: sun 5.jpg

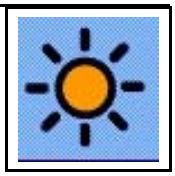


Function: Safety and Warning Information
Weather information
General

ID #: 246
Message: Sunny
Source: http://www.weather.com/
Notes:
File: sun 6.jpg

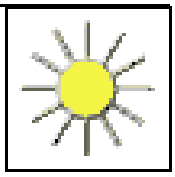


ID #: 345
Message: Sunny
Source: http://www.intellicast.com/
Notes:
File: sun 7.jpg

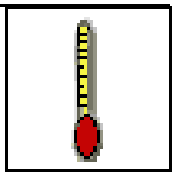


ID #: 69
Message: Sunny
Source: http://www.accuweather.com/
Notes:
File: sun 8.jpg

ID #: 210
Message: Sunny
Source: Industry
Notes:
File: weatherSunny.gif



ID #: 129
Message: Temperature
Source: Industry
Notes:
File: weatherThermometer.gif



Icon Details by Icon Type

Function: Safety and Warning Information
Weather information
General

ID #: 18

Message: Wind

Source: http://www.intellicast.com/

Notes:

File: cloud 5.jpg

ID #: 199

Message: Wind indicator

Source: Industry

Notes:

File: weatherWindicon.gif

CHAPTER 9: TUTORIALS

TUTORIAL 1: ANALYSIS OF RANK ORDER DATA

In this tutorial, we describe the types of information that can be obtained from rank-order data. We assume that the data is collected in the following manner. A total of n_j judges are asked to rank order n_s stimuli (e.g., icons) with respect to some attribute (e.g., appropriateness for a specific message). Usually the whole set of stimuli is presented together, and the judges are allowed to proceed as they wish as long as each judge comes through with a single rank order along the attribute specified. If many stimuli are presented, it might be useful for the judges to sort them roughly into grades before attempting the final ranking. A hypothetical data set is presented in table 9-1. These hypothetical data might be obtained from 10 individuals who rank ordered 5 icons (icons A, B, C, D, and E) in appropriateness for a specific message. The icons would be assigned ranks of 1-5, with "1" corresponding to the icon considered to be the most appropriate.[1]

Table 9-1. Sample Data Set: Ranks Assigned to 5 Icons by 10 Judges

Judge	Ranks Assigned				
	Icon A	Icon B	Icon C	Icon D	Icon E
1	4	2	1	3	5
2	4	2	1	3	5
3	2	1	3	4	5
4	3	1	2	4	5
5	3	4	1	2	5
6	3	2	1	4	5
7	4	3	1	2	5
8	4	2	3	1	5
9	4	2	1	3	5
10	4	1	2	3	5

Our goal is to investigate whether and how much the judged stimuli differ with respect to the attribute of interest. This goal can be accomplished at different levels using different methods of

[1] When obtaining initial rank scores, lower rank scores are assigned to the icons judged to be more appropriate in accordance with traditional and accepted ranking methods. Elsewhere in this tutorial (e.g., see page 9-5), we see that the icons judged to be more appropriate are designated with higher values, not lower values. This reversal occurs when computing *p*, *z*, and R values, and is an expected mathematical outcome of transforming rank score values to interval-scale values.

analysis. In the following sections, we discuss some of these methods. First, we indicate a quick way to determine a composite rank order for the stimuli. Second, we discuss the use of mean ranks. Third, we outline two methods of obtaining scores for the stimuli on an interval scale. In addition to a general rank ordering, these scores provide an indication of relative differences among the stimuli. Finally, we discuss the use of more advanced and complex statistical methods that allow us to test whether the stimuli are truly different with respect to the attribute of interest.

1. DERIVING RANK ORDER FROM SUMS OF ASSIGNED RANKS

A composite ranking for the stimuli can be obtained by computing the sums of the rank values assigned to each of the stimulus. The order of the magnitudes of the sums will indicate an ordering of the stimuli, with the lowest sum corresponding to the stimulus judged as the best. For example, for the raw data of table 9-1, we obtain the sums presented in table 9-2, which indicate the following composite rank order from the most to least appropriate icon: C, B, D, A, and E.

Table 9-2. A Composite Ranking of Icons Obtained from Sums of Assigned Ranks

	Icon A	Icon B	Icon C	Icon D	Icon E
Sum of assigned ranks (S)	35	20	16	29	50
Composite rank	4	2	1	3	5

2. OBTAINING MEAN RANKS

Mean ranks are obtained for each icon by dividing the sum of the ranks assigned to that icon by the number of judges. For example, for the raw data of table 9-1, the mean rank of icon A is 35/10 = 3.5. Mean ranks corresponding to all five icons in the sample data set are presented in table 9-3. In general, mean ranks will somewhat agree with the composite ranks in both order and spacing.

Table 9-3. Mean Rank of Each of the Icons

	Icon A	Icon B	Icon C	Icon D	Icon E
Sum of assigned ranks (S)	35	20	16	29	50
Mean Rank (M_r) = S/n_j	3.5	2	1.6	2.9	5

It should be noted that mean ranks should never be used to judge the absolute differences between the stimuli. For example, on the basis of the data presented in table 9-3, we could not conclude that icon E was judged to be 1.5 times more inappropriate than icon A. At best, mean ranks provide an indication of relative differences. For example, mean ranks in table 9-3 indicate that the difference between icons B and A is the same as the difference between icon A

and E. However, the reader should be warned that rank values are strictly ordinal numbers[2] and there is little numerical meaning to be attached to means of such values. To obtain more precise relative differences between the stimuli, we recommend the use of the scaling methods discussed in the next section.

3. OBTAINING INTERVAL-SCALE VALUES

As mentioned above, rank data (i.e., the rank orders produced by the judges) are on an ordinal scale. This scale arranges things in order of magnitude, but does not reveal the magnitude of the differences between them. An interval scale, on the other hand, allows statements about how much difference there is between two objects. A good example for an interval scale is the Fahrenheit scale of temperature. Here, it is meaningful to say that there is as much difference between 60 ºF and 70 ºF as there is between 70 ºF and 80 ºF. Note, however, that interval-scale values are not absolute magnitudes. For instance, it is not accurate to say that 80 ºF is twice as high as 40 ºF.

Using rank orders generated by a group of judges, it is possible to obtain interval-scale values for the ranked items. Below, we discuss two different methods of obtaining interval-scale values using rank order data: (1) Choice Score Method, and (2) Torgerson's Categorical Scaling Method. The reader should keep in mind that the values obtained using either of the scaling methods are not meaningful in absolute terms, but that they give only an indication of relative differences between the stimuli. As an example, let us assume that we have obtained scale values of 2.5, 5, and 7.5 for icons A, B, and C, respectively. Based on these values, we cannot conclude that icon A is three times as good (or appropriate) as icon C. However, we can say that there is as much difference between icons A and B as there is between B and C. Such information can be important to icon designers, who frequently must make tradeoffs among design issues such as cost, driver performance, and driver preferences. Converting the rank-order data to an interval scale allows for more systematic and rigorous tradeoff analyses to be conducted.

A. Choice Score Method

This scaling procedure, described in Engen (1971), converts rank orders to choice frequencies, then to p values, and finally to z scores (unit normal deviates). The z scores obtained represent scale values for the stimuli on a psychological scale with equal intervals on the assumption that the rankings are normally distributed. The procedure is outlined below; the computations for the sample data set are shown in table 9-4.

[2] Ordinal numbers arrange things in order of magnitude. They make possible comparisons of objects of the type "greater than" or "less than," but do not reveal the magnitude of the differences between them.

Table 9-4. Computations for the Choice Score Method

Step		Icon A	Icon B	Icon C	Icon D	Icon E	Mean*
1	Mean Rank (M_r)	3.50	2.00	1.60	2.90	5.00	3.00
2	$M_c = n_s - M_r$	1.50	3.00	3.40	2.10	0.00	2.00
3	$p = M_c/(n_s - 1)$	0.38	0.75	0.85	0.53	0.00	0.50
4	z	-0.31	0.67	1.04	0.08	–	–
5	$R = 5z + 6$	4.45	9.35	11.20	6.40	–	–

* The following can be used to check the calculations: (1) mean M_r must be equal to $(n_s+1)/2$; (2) mean choice (M_c) must be equal to $(n_s-1)/2$; (3) mean p must be equal to 0.5.

Step 1. Calculate the mean rank (M_r) assigned to each stimulus (see table 9-2).

Step 2. Calculate a mean choice score (M_c) for each stimulus by subtracting the mean rank from the number of stimuli (n_s). For example, the mean choice M_c score for icon A of the sample data set is 5 – 3.5 = 1.5.

Step 3. Convert the mean choice scores (M_c) into p values by dividing them by $(n_s - 1)$. For example, the p value for icon A of the sample data set is 1.5/4 = 0.38.

The computations performed so far can be checked with the following:

(1) Mean M_r must equal $(n_s + 1)/2$,
(2) Mean M_c must equal $(n_s - 1)/2$, and
(3) Mean p must equal 0.5.

For example, in table 9-4,

(1) Mean M_r = (3.50 + 2.00 + 1.60 + 2.90 + 5.00) / 5 = 3.00,
(2) Mean M_c = (1.50 + 3.00 + 3.40 + 2.10 + 0.00) / 5 = 2.00, and
(3) Mean p = (0.38 + 0.75 + 0.85 + 0.53 +0.00) /5 = 0.50.

Step 4. Convert the p values into z scores using table 9-5.

The z scores obtained in step 4 represent scores for the stimuli on an interval scale. Because the z values are generally awkward numbers to use, we recommend a linear transformation of the z values to a more convenient range as explained in step 5 below. (This transformation is similar to converting ºF temperature to ºC temperature.)

Step 5. *(Optional)* Obtain a linear transformation of the z scores (i.e., multiply the z scores by a constant and add a constant). In table 9-4, we arbitrarily use the transformation $R = 5z + 6$; any other linear transformation (e.g., $R = 2z + 1$) can be used. The purpose of this transformation is to obtain scores in a more convenient range than the z scores obtained in step 4.

The *R* values, like the *z* values obtained in step 4, represent interval-scale values for the stimuli, with higher values indicating stimuli judged to be better with respect to the attribute of interest. As seen in table 9-4, icon E cannot be assigned a scale value. This results from the fact that icon E was invariably placed in ranked 5. If a stimulus is placed in the same rank by all judges, it cannot be assigned a scale value using this procedure.

Table 9-5. *p* – *z* Conversion Table

***p* – *z* values**										
p	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
z	-2.33	-2.05	-1.88	-1.75	-1.64	-1.55	-1.48	--1.41	-1.34	-1.28
p	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.02
z	-1.23	-1.18	-1.13	-1.08	-1.04	-0.99	-0.95	-0.92	-0.88	-0.84
p	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30
z	-0.81	-0.77	-0.74	-0.71	-0.67	-0.64	-0.61	-0.58	-0.55	-0.52
p	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40
z	-0.50	-0.47	-0.44	-0.41	-0.39	-0.36	-0.33	-0.31	-0.28	-0.25
p	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50
z	-0.23	-0.20	-0.18	-0.15	-0.13	-0.10	-0.08	-0.05	-0.03	-0.00
p	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60
z	+0.03	+0.05	+0.08	+0.10	+0.13	+0.15	+0.18	+0.20	+0.23	+0.25
p	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70
z	+0.28	+0.31	+0.33	+0.36	+0.39	+0.41	+0.44	+0.47	+0.50	+0.52
p	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80
z	+0.55	+0.58	+0.61	+0.64	+0.67	+0.71	+0.74	+0.77	+0.81	+0.84
p	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90
z	+0.88	+0.92	+0.95	+0.99	+1.04	+1.08	+1.13	+1.18	+1.23	+1.28
p	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	0.995
z	+1.34	+1.41	+1.48	+1.55	+1.64	+1.75	+1.88	+2.05	+2.33	+2.58

B. Torgerson's Categorical Scaling Method

This scaling method is based on Torgerson's Law of Categorical Judgment.[3] (Torgerson, 1962). While it involves more computational steps than the Choice Score Method, it also seems to reflect stronger theoretical foundations. For the raw data of table 9-1, the two scaling methods produce similar scores; however, we cannot conclude that the scale values will be the same in all cases.

The method proceeds as follows:

Step 1. Prepare a matrix (matrix A) that indicates the frequency with which each stimulus (icon) is placed in each rank. For the raw data of table 9-1, matrix A is as seen in table 9-6. The rows of this matrix represent the stimuli and the columns, the ranks. In each column is the number of times a given icon received that rank. Icons are treated as *j* in the equations; ranks as *g*. For example, the element in the fourth row, third column (4) is the number of times icon D was placed in rank 3.

Table 9-6. Matrix A

Icon	Rank 1	2	3	4	5
A	0	1	3	6	0
B	3	5	1	1	0
C	6	2	2	0	0
D	1	2	4	3	0
E	0	0	0	0	10

[3] Torgerson's Law of Categorical Judgment is a set of equations relating parameters of stimuli and category boundaries to a set of cumulative proportions derived from the proportion of times each stimulus is judged to be in each category of a set of categories ordered with respect to a given attribute The complete form of the law is as follows:

$$t_g - s_j = x_{jg}(\sigma_j^2 + \sigma_g^2 - 2r_{jg}\sigma_j\sigma_g)^{1/2} \qquad (j = 1,2..n;\ g = 1,2..m)$$

where
n = number of stimuli
m+1 = number of categories
s_j = scale value of stimulus j
t_g = mean location of the gth category boundary
σ_j = discriminal dispersion of stimulus j
σ_g = dispersion of the g^{th} category boundary
r_{jg} = correlation between momentary values associated with stimuli j and category boundary g
x_{jg} = unit normal deviate corresponding to the proportion of times stimulus j is sorted below boundary g

In the solution procedure described, it is assumed that σ_j is constant, σ_g is constant, and r_{jg} is constant for all values of j and g.

Step 2. Obtain matrix B by identifying any elements of matrix A that are equal to the number of judges (n_j) and removing the corresponding rows and columns from the matrix. For example, in matrix A of table 9-6, we identify one element that is equal to 10 (n_j), and we delete the corresponding row and column (fifth row, and fifth column) to obtain matrix B of table 9-7. This step removes from the data matrix any stimuli that have been placed in the same rank by all judges. Such stimuli cannot be assigned an interval-scale value using this procedure, and their exclusion simplifies the computations.

Table 9-7. Matrix B

Icon	Rank 1	2	3	4
A	0	1	3	6
B	3	5	1	1
C	6	2	2	0
D	1	2	4	3

Step 3. Construct matrix C by cumulating the rows of matrix B from the left. For matrix B of table 9-7, matrix C is as seen in table 9-8. The first row of this matrix is computed as follows: 0, 0 + 1 = 1, 0 + 1 + 3 = 4, 0 + 1 + 3 + 6 = 10. The elements in the last column should be equal to the number of judges.

Table 9-8. Matrix C

Icon	Rank 1	2	3	4
A	0	1	4	10
B	3	8	9	10
C	6	8	10	10
D	1	3	7	10

Step 4. Construct matrix D by dividing each element of matrix C by the rightmost element of the corresponding row, and then obtain row totals. For matrix C of table 9-8, matrix D is as seen in table 9-9. The first row of this matrix is computed as follows: 0/10 = 0, 1/10 = 0.1, 4/10 = 0.4, 10/10 = 1. The row total of this row is 0 + 0.1 + 0.4 + 1 = 1.5.

Table 9-9. Matrix D

Icon	Rank 1	2	3	4	Row Total
A	0	0.1	0.4	1	1.5
B	0.3	0.8	0.9	1	3.0
C	0.6	0.8	1	1	3.4
D	0.1	0.3	0.7	1	2.1

Step 5. Construct matrix E by ordering the rows of matrix D in decreasing magnitude of row totals, and leaving out the rightmost column. For the matrix D of table 9-9, matrix E is as seen in table 9-10. The row that corresponds to icon C has the highest row total (3.4), therefore, it is the first row of matrix E. Rows corresponding to icons B, D, and A follow in that order.

Table 9-10. Matrix E

		Rank		
		1	2	3
Icon	C	0.6	0.8	1
	B	0.3	0.8	0.9
	D	0.1	0.3	0.7
	A	0	0.1	0.4

Step 6. Construct matrix F, whose elements are equal to the *z*-scores (from table 9-5) of the corresponding elements of matrix E. For matrix E of table 9-10, matrix F is as seen in table 9-11. The element in the second row, third column (1.28) is the *z*-score corresponding to 0.9 in table 9-5. The elements of this matrix will be negative for all proportions below 0.5, and positive for all proportions above 0.5. Any cells of matrix E that contain proportions of 0 or 1 cannot be transformed into a *z*-score, and are left vacant.

Table 9-11. Matrix F

		Rank		
		1	2	3
Icon	C	0.25	0.84	–
	B	-0.52	0.84	1.28
	D	-1.28	-0.52	0.52
	A	–	-1.28	-0.25

Step 7. Construct matrix G, which shows the differences in the rows of matrix F, and obtain row means. The first row of matrix G is computed by subtracting row 2 of matrix F from row 1 of matrix F; the remaining rows are computed similarly. For matrix F of table 9-11, matrix G is as seen in table 9-12. The first row of matrix F is constructed as follows: 0.25 – (–0.52) = 0.77, 0.84 – 0.84 = 0, vacant. In computing the row means, vacant cells are excluded. For instance, the mean of row 1 in table 9-12 is (0.77 + 0)/2 = 0.39.

Table 9-12. Matrix G

		Rank			
		1	2	3	Row Mean
Icon	C-B	0.77	0	–	0.39
	B-D	0.76	1.37	0.76	0.96
	D-A	–	0.76	0.78	0.77

Step 8. Compute interval-scale values for the stimuli by listing the stimuli in the same order as in matrix F, assigning a score of 0 to the last stimulus in the list, and cumulating toward the top using the row means of matrix G. For matrix G of table 9-12, the scale values are computed as shown in table 9-13. The first column lists the icons in the same order they were listed in matrix F of table 9-11; the second column lists the row means of matrix G of table 9-12. We first assign a scale value of 0 to icon A. We then compute the scale value of icon D as follows: 0+0.77 = 0.77. Scale values for icons B and C are assigned in a similar manner.

Table 9-13. Step 8: Assigning Interval-Scale Values

Icon	Row Means of Matrix G (from table 9-12)	Scale Value
C	0.39 (C-B)	0 + 0.77 + 0.96 + 0.39 = 2.12
B	0.96 (B-D)	0 + 0.77 + 0.96 = 1.73
D	0.77 (D-A)	0 + 0.77 = 0.77
A		0

Assign scale values by cumulating from bottom to top

Note that higher scale values indicate better (i.e., more appropriate) icons. Note also that we cannot assign a scale value for icon E, but we know that its score would be lower than the scores of all other icons, as it was placed in rank 5 by all judges.

4. CONDUCTING A TEST OF SIGNIFICANCE

Using the methods discussed so far, we might obtain a composite rank order for the stimuli with no ties, and a different interval-scale score for each stimulus. Does that mean that the stimuli are truly different from each other with respect to the attribute of interest? Not necessarily. To answer this question, we need to perform a test of significance. A test of significance allows us to determine, with a specified risk of error, whether the observed difference is really meaningful, or whether we might expect the same difference to occur merely because of chance factors.

On rank-order data from a group of judges (e.g., the raw data of table 9-1), we can conduct a significance test based on Friedman Rank Sums to determine whether there are or are not real differences between the stimuli. A detailed explanation of this statistical test is beyond the scope of this tutorial, but the general outline is as follows:

1. Compute a summary score from the data. This summary score reflects the differences between the ranks assigned to each stimulus. The more different the ranks of each stimulus, the greater will be this summary score.

2. Compare this summary score to a criterion value. This criterion indicates how big the summary score can get if there are no true differences between the stimuli. The criterion will vary depending on the number of observations in the data set and the risk of error one is willing to take. If the summary score is greater than the criterion, conclude that the stimuli are truly different with respect to the attribute of interest.

Using the Friedman test, we can test the equivalence of all stimuli, or perform pairwise comparisons. For a detailed explanation of this statistical test, readers should refer to a text on nonparametric statistical methods (e.g., Hollander & Wolfe, 1973). The Friedman test is also available in several commercial statistical software packages.

SUMMARY

We have discussed several methods of analyzing rank order data. These are summarized in table 9-14. This table provides a guide for the designer in determining which method(s) would be appropriate for the design problem at hand.

Table 9-14. Summary of Methods Discussed for Analyzing Rank Order Data

Method	Outcome	Computational Complexity
Compute sum of assigned ranks	Provides a composite ranking	Simple
Compute mean ranks	Provides a composite ranking; will somewhat agree with the spacing of the composite ranks	Simple
Compute interval-scale values for the stimuli using one of the following: 1) Choice score method 2) Torgerson's categorical scaling method	Provides an indication of relative differences between the stimuli	Requires a series of simple computations
Conduct a test of significance	Provides evidence for concluding, with a specified risk of error, that there are or are not real differences between the stimuli	Complex, can be performed using statistical software packages

References:

1. Engen, T. (1971). Psychophysics: Scaling methods. In J. W. Kling and L. A. Riggs (Eds.), *Woodworth and Schlosberg's experimental psychology* (3rd. ed.) (pp. 47-86). New York: Holt, Rinehart, & Winston, Inc.
2. Hollander, M., and Wolfe, D. A. (1973). *Nonparametric statistical methods*. New York: J. Wiley & Sons, Inc.
3. Torgerson, W. S. (1962). *Theory and methods of scaling*. New York: J. Wiley & Sons, Inc.

TUTORIAL 2: PROVIDING SUBJECTS WITH CONTEXT DURING ICON EVALUATIONS

This tutorial provides some guidance and examples of ways to provide appropriate context to experimental subjects during comprehension evaluations of candidate icons. In real-world driving, icons are presented in the *context* of certain in-vehicle capabilities and driving circumstances. As such, evaluations of in-vehicle icons should include a description of the context in which icons will be presented and used. However, icon evaluations should avoid providing either too little or too much context to experimental subjects. If too little context is provided, unrealistically low comprehension scores may result because the subjects may be unable to connect a visual icon with the many possible icon meanings. If too much context is provided, unrealistically high comprehension scores may result because the subjects have been cued for a certain response by the specificity of the context. Both these extremes should be avoided.

The context provided to subjects should describe the: (1) general capabilities of the in-vehicle system that will be used to present the icons and (2) general driving circumstances associated with the presentation of the icon by the in-vehicle system. For example, an evaluation of an icon intended to warn drivers of a problem with the passive restraint system on their vehicle might provide the following "system capabilities" information to subjects:

> *Our purpose is to investigate issues related to the use of graphical icons in the in-vehicle environment. Recent advances in automotive technology have allowed the development of various In-Vehicle Information Systems (IVIS) that present a wide range of trip, vehicle, and safety information to drivers. Much of this information will be provided to drivers through color displays located on the instrument panel or center console of the vehicle. These display systems might present information such as:*

- ***Adaptive Cruise Control**: An improved cruise control system that maintains adequate spacing between the driver's car and the vehicle ahead.*

- ***Augmented Signage**: System that displays regulatory and road condition icons for the road on which the driver is presently driving. Icons would be similar to the signs posted along the roadside.*

- ***Collision Avoidance System**: On-board sensor and display systems that warn the driver of an impending collision with another vehicle or object, vehicle lane departure, and other motion-based hazards.*

- ***Motorist Services**: Information that provides an in-vehicle "Yellow Pages" function to drivers. This directory would present information regarding the availability and locations of motorist services such as gas stations, restaurants, hotels, or recreational activities.*

- ***Trip Navigation****: Information that provides the driver with route assistance and trip planning. This includes driving directions, cautions about certain routes, current traffic conditions, road construction, or weather updates.*

- ***Vehicle Condition Monitoring:*** *Device that informs the driver of problems with the vehicle or vehicle systems (oil, tire pressure, engine, etc.).*

The following "driving circumstances" information could be provided to drivers:

Figure 9-1. Sample Icon

You have just started your car.

A group of icons appears on your In-Vehicle Information System, including this icon.

What do you think this icon means?

Similarly, in the context of evaluating comprehension for a specific Motorists Services icon, the following "driving circumstances" information could be provided:

Figure 9-2. Motorists Services Icon

You are driving on a highway.

This icon appears on the In-Vehicle Information System installed in your car.

What do you think this icon means?

CHAPTER 10: SENSORY MODALITY DESIGN TOOL

This section of the guidelines provides designers of in-vehicle icons with a design tool that can help determine the most appropriate display modality for presenting in-vehicle information elements. This tool was originally developed as part of the preliminary assessment of symbols and is described in more detail in Lee et al. (1998). The tool was generated based on an examination of the general design rules found in relevant literature.

Questions:		Very Low	Low	Medium	High	Very High	**Visual**	**Auditory**	**Tactile**
1. What is the degree of urgency of the message?	**Visual**	4	3	2	1	1	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	1	2	3	4	5			☐
2. To what degree might the message be referred to again later?	**Visual**	1	2	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	2	0	0	0			☐
3. What is the overall level of complexity of the message?	**Visual**	3	3	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	1	0	0	0			☐
4. To what degree does the message deal with a future action in time?	**Visual**	5	4	3	3	3	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	0	0	0	1	5			☐
5. To what degree does the message refer to locations in space?	**Visual**	3	3	3	4	5	☐		
	Auditory	5	4	3	2	1		☐	
	Tactile	5	1	0	0	0			☐
IVIS Message: _____							**sum**	**sum**	**sum**
_____							☐	☐	☐
Other Relevant Factors: _____							**Visual**	**Auditory**	**Tactile**
_____									

Figure 10-1. Sensory Modality Design Tool

The design tool asks designers to respond to several questions independently. For each question, their response will range from "very low" to "very high." Each response is associated with a point value for the three modalities (visual, auditory, and tactile). After all five questions have been answered, the point values are totaled for each of the modalities. The steps a designer must complete to use this design tool are summarized below and shown in detail in the figure on the following page.

Step 1: Identify and Define Driver Message.
Step 2: Determine Appropriate Response to the Question and Circle Scores.
Step 3: Transpose Scores to Visual, Auditory, and Tactile Columns.
Step 4: Complete Steps 2 and 3 for Questions 2 through 5.
Step 5: Total Columns.

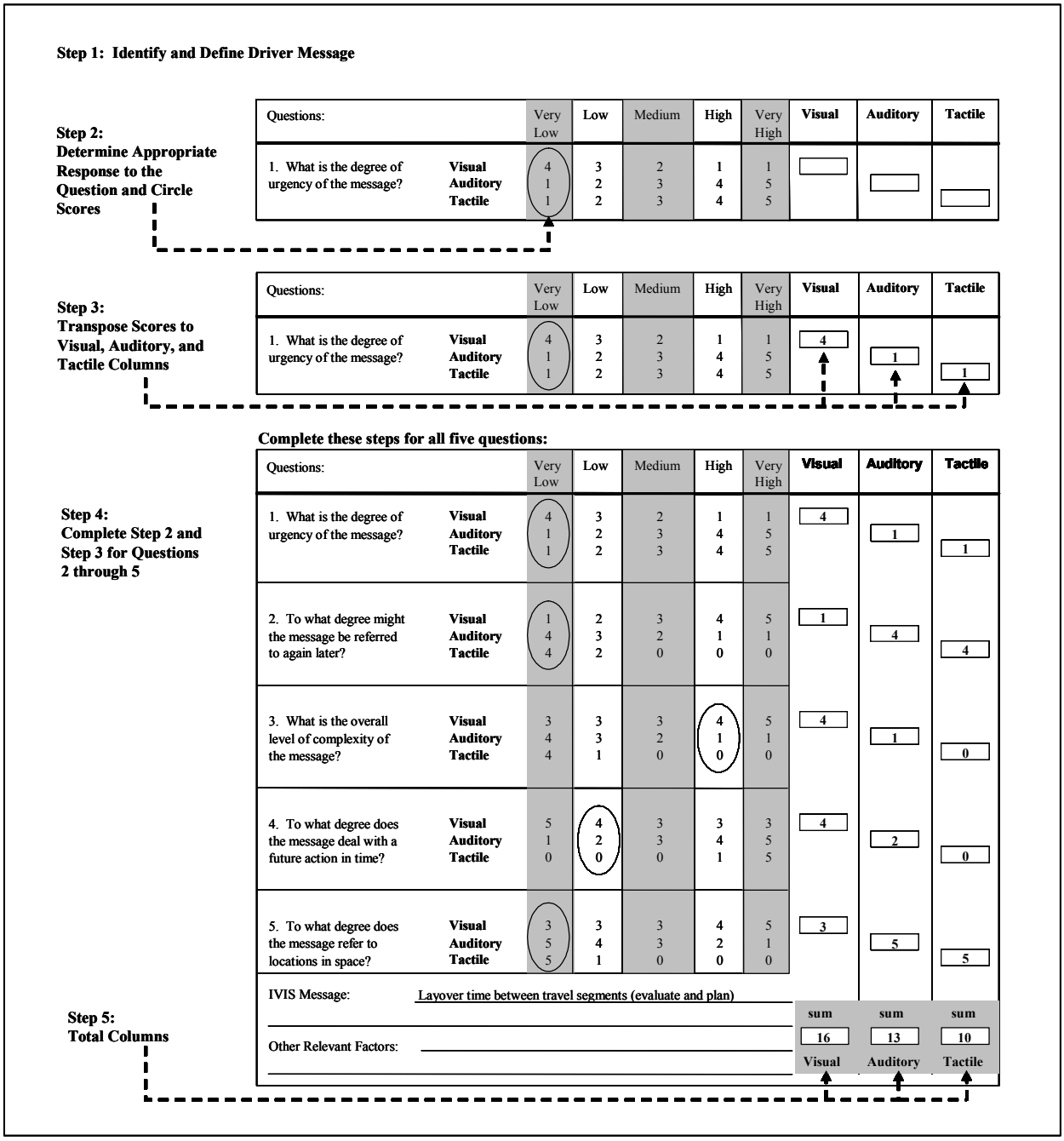


Figure 10-2. Steps for Using the Sensory Modality Design Tool

Determining the most appropriate modality is not always as easy as selecting the one that receives the highest point value. In cases where two modalities receive high scores (15 or greater), it is suggested that the information be presented using some combination of the two. This will reflect the fact that both modalities are necessary to adequately present the information. In cases where two modalities receive the same score or they are only one point apart, it is suggested that the information be presented using either of the two modalities. In all other cases, the modality that receives the highest score is the suggested mode of presentation for that piece of information. Decisions regarding which one to use may be based on additional information regarding context or display constraints. If, however, two modalities receive scores that are both higher than 15 *and* only one point apart, then the benefits of using both modalities outweigh other design considerations and the information should be presented by combining the two modalities, instead of choosing between them. By prioritizing the rules below, the designer will know which one to use in cases where more than one is applicable. The rules for determining the most appropriate modality can be summarized as follows.

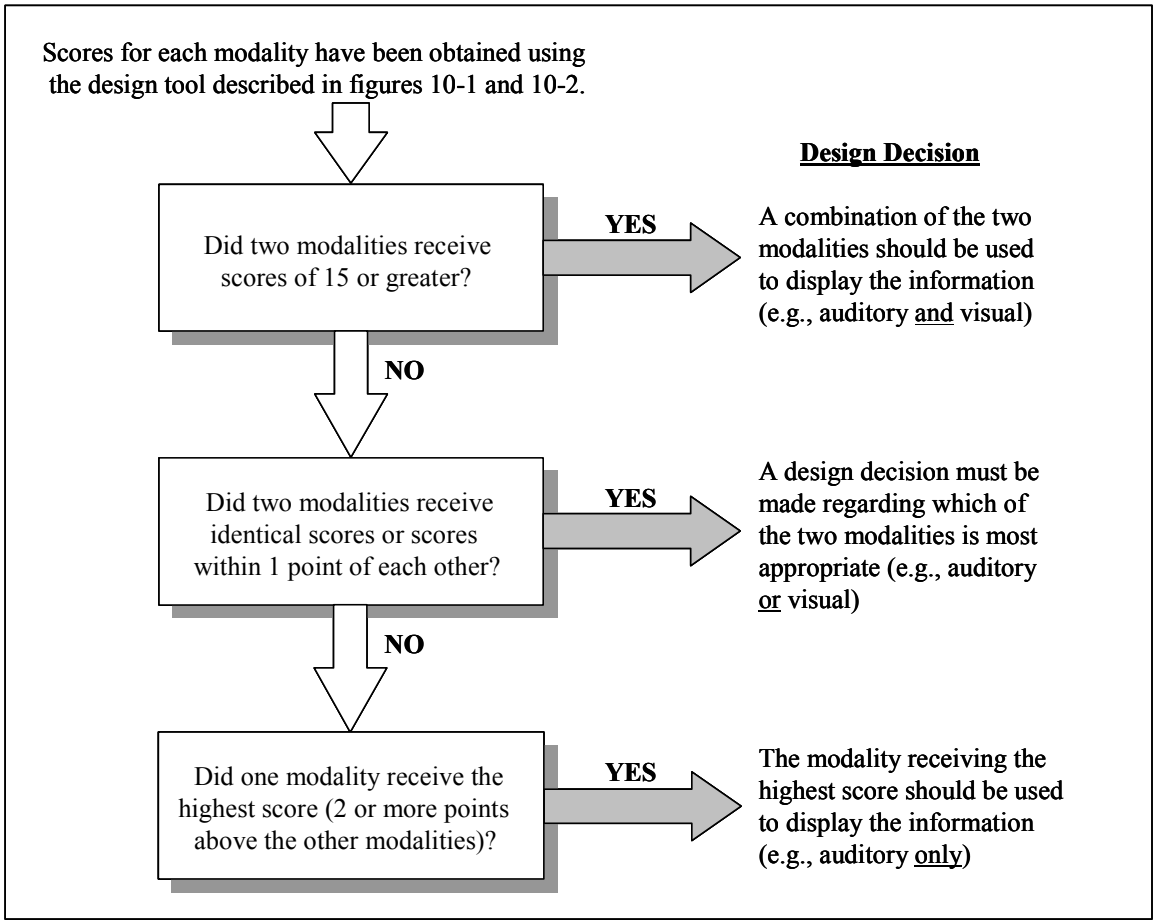


Figure 10-3. Rules for Determining Display Modality

In the above flow diagram, the designer is asked to address each rule in the order of its priority. For example, if the auditory modality received a score of 17 and the visual scores 16, the first question a designer would ask is "Did two modalities receive scores of 15 or greater?" Since the answer is "yes," the design decision states that "a combination of the two modalities should be used to display the information." However, if the auditory modality had received a score of 14 and the visual a score of 15, the answer to that first question would be "no." In this case, a designer would then proceed to the next question "Do the two modalities receive identical scores or scores within one point of each other?" Since the answer is "yes," the design decision states that "a decision must be made regarding which of the two modalities is most appropriate." In the last case (i.e., the auditory modality receives a score of 12 and the visual a score of 15), the answer to both the first and the second question would be "no." Therefore, the designer would proceed to the third question and the subsequent design decision, which would be to present the modality that had received the highest score.

CHAPTER 11: LIST OF EQUATIONS

Determining the Appropriate Luminance Uniformity within an Icon

Page 3-2

$$\text{Percent Element Nonuniformity} = \frac{(\text{Luminance}_{min}) - (\text{Luminance}_{max})}{(\text{Luminance}_{max})} \quad (1)$$

where: Luminance_{min} = the smaller luminance value
Luminance_{max} = the greater luminance value

Determining the Appropriate Contrast within an Icon

Page 3-4

Here, we define contrast as a ratio between maximum and minimum luminance values, or:

$$\text{Contrast ratio} = \frac{\text{Luminance}_{max}}{\text{Luminance}_{min}} \quad (2)$$

where:

Luminance_{max} = luminance emitted by the area or element of greatest intensity.
Luminance_{min} = luminance emitted by the area or element of least intensity

Determining the Appropriate Size of Icon Components

Page 3-6

If Known	Use These Formulas for Calculating These Unknowns		
	Visual Angle	**Symbol Height**	**Distance**
Distance and Symbol Height	$\text{Arctan}\left[\frac{\text{Symbol Height}}{\text{Distance}}\right]$ (3) or $\left[\frac{3438\ (\text{Height})}{\text{Distance}}\right] \div 60$ (4)	–	–
Distance and Visual Angle	–	Distance H [Tangent (Visual Angle)] (5)	–
Visual Angle and Symbol Height	–	–	$\frac{\text{Symbol Height}}{\text{Tangent (Visual Angle)}}$ (6)

where: Symbol Height = the height of the symbology
Distance = distance from viewer's eyepoint to the display
Visual Angle = angle in degrees
Height and Distance use the same unit of measure (e.g., meters, yards, etc.)

The Effects of Color on Icon Legibility

Page 3-10

$$\Delta E\ (CIE\ Yu'\ v') = \left[\left(155 \left(\frac{\Delta Y}{Ym} \right) \right)^2 + (367\ \Delta u')^2 + (167\ \Delta v')^2 \right]^{0.5} \qquad (7)$$

where:

$\Delta E\ (CIE\ Yu'\ v'$	=	the color contrast metric
ΔY	=	difference in luminance between text (symbology) and background
Ym	=	the maximum luminance of text (symbology) or background
$\Delta u'$	=	difference between u' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)
$\Delta v'$	=	difference between v' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)

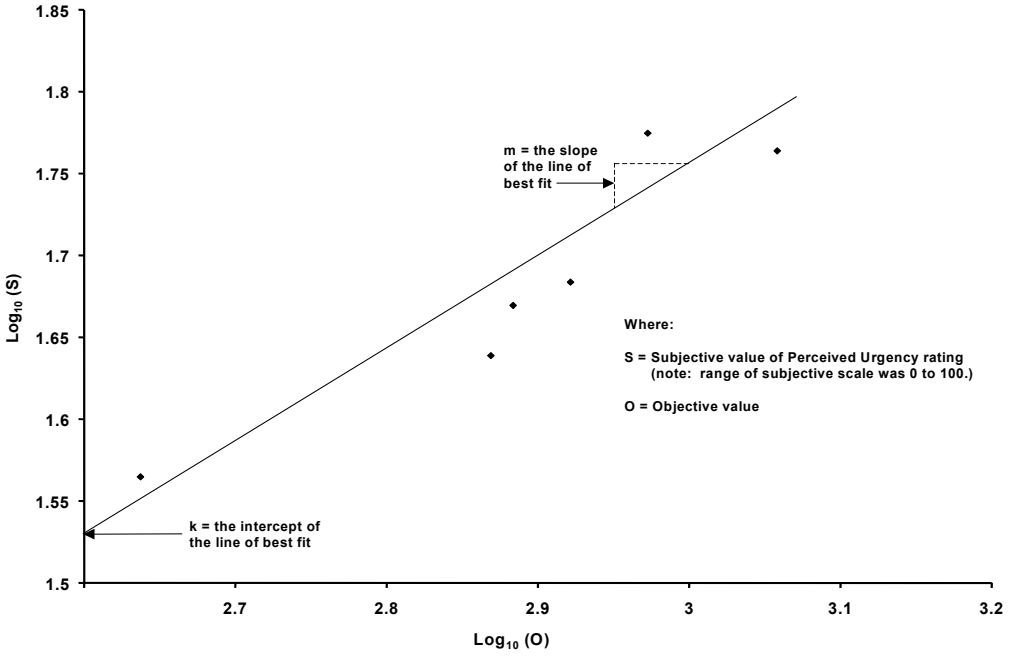
NOTE: The constants 155, 367, and 167 in equation 7 are empirically derived weights (reference 1).

Perceived Urgency of Auditory Signals

Page 6-16

Example of Using Steven's Power Law for Producing Urgency Exponents (see references 2 and 3 for more detailed explanations and examples)

$$S = kO^m \qquad (8)$$

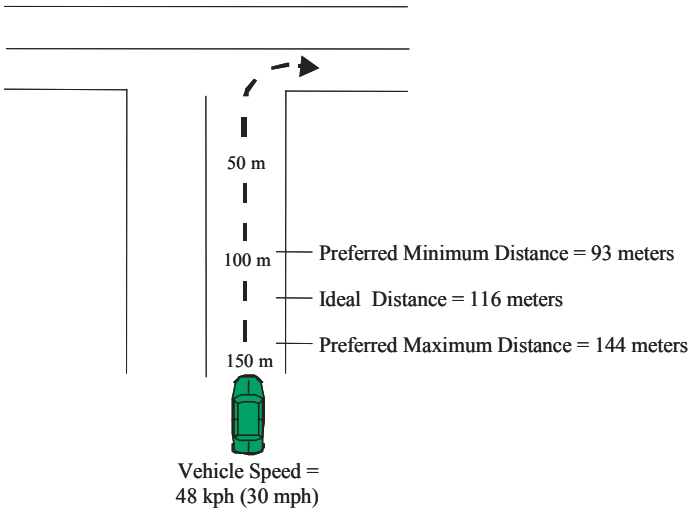


Equations for Determining the Appropriate Timing of an Instruction

EQUATIONS[1]	
Preferred Minimum Distance	= (Speed x 1.637) + 14.799 (9)
Ideal Distance	= (Speed x 1.973) + 21.307 (10)
Preferred Maximum Distance	= (Speed x 2.222) + 37.144 (11)

[1] where speed is in km/h and distances are in meters

Example of the Suggested Timing for Navigational Information



CHAPTER 12: GLOSSARY

ACC	Automated Cruise Control.
Appropriateness Ranking Test	Refers to a test to screen the candidate symbols generated during the Production Test and to select the best for further testing.
ASR	Automatic Speech Recognition.
ATIS	Advanced Traveler Information Systems.
Auditory signals	Refers to simple tones, earcons, auditory icons, or speech messages.
Auditory icons	These are familiar environmental sounds (iconic, metaphorical, and symbolic) that intuitively convey information about the object or action that they represent
Augmentation of icons with auditory information	To make the message clearer or more salient, some type of auditory signal is included with an icon.
Automatic Speech Recognition (ASR) systems	Devices that recognize human speech and, in an in-vehicle context, treat speech commands as inputs to an IVIS device. Currently, ASR is viewed as an enabling technology in intelligent transportation system (ITS) development, allowing the driver to interact with the IVIS device while maintaining his/her eyes on the road and hands on the wheel.
CAS	Collision Avoidance System.
CIE	Commission Internationale de l'Eclairage (International Lighting Commision).
Color coding	Refers to the use of chromaticity to differentially identify items in a display systematically. The categories used to color code objects on a display depend upon the tasks required of the operators.
Composition of an icon	Composition of an icon refers to the parts that comprise an icon.

Comprehension/ Recognition Test	This test is an evaluation technique that provides a means to determine which of a number of candidate icons/symbols for a concept is best understood by a sample of subjects who represent the user population.
Contrast	The relationship between the luminance of a symbol and the luminance of the symbol's background.
Conveying the effect of actions with icons	Refers to the ability of an icon to help the driver anticipate the effect of selecting a particular system function or option.
Conveying system status with icons	Refers to changing icon appearance to convey changes in the system state.
Conveying urgency with icons	Urgency is conveyed by adjusting icon characteristics to reflect the appropriate level of urgency of the situation.
CRT	Cathode Ray Tube.
CVO	Commercial Vehicle Operations.
CVO-specific icons	Icons that relate to commercial vehicle operations.
dB	Decibel, a unit for expressing relative difference in power; usually between acoustic or electrical signals, equal to ten times the common logarithm of the ratio of the two levels.
Development process for in-vehicle icons	This process reflects the specific needs, goals, and constraints associated with individual design efforts, providing important information that will increase the effectiveness and utility of icons.
Display modality	Refers to decisions regarding the use of visual, auditory, or haptic stimuli (or some combination of these three modes) to inform, alert, or warn the driver of some condition or situation.
DOT	Department of Transportation.
DVI	Driver-Vehicle Interface.
Earcons	Auditory signals that present information through musical tones that can be used in structured combinations to create auditory messages.

Evaluation of in-vehicle icons	The process of determining whether an icon, or an integrated set of icons, meets specific criteria in areas such as legibility, recognition, interpretation, and driver preferences.
FHWA	Federal Highway Administration.
Filtering sign information	Refers to allowing the driver to select the on-road signage they would like to receive in-vehicle. The driver will be able to filter both notification and guidance sign information. However, regulatory sign information will be presented to the driver regardless of preference.
fL	Foot lambert.
Flash rate	The rate at which a signal alternates between an illuminated and a non-illuminated state.
Flashing icons	Icons that flash on and off in a predetermined on/off cycle.
FMVSS	Federal Motor Vehicle Safety Standards.
Font segments	Refers to electronic displays in which characters are formed by illuminating discrete segments within a basic symbol pattern. The majority of electronic displays using this technique employ 7-segment patterns to generate numerals (e.g., digital speedometers and clocks); however, 14-segment and 16-segment patterns are also available for the generation of complete alphanumeric sets.
FOV	Field-of-View.
Grouping icons	Grouping facilitates icon identification as a set of related messages or similar commands.
Guideline format	The method used to present guidelines to system designers and developers.
HUD	Head-Up Display.
Hz	Hertz, a unit of frequency equal to one cycle per second.
Icon	A visual representation or image used to symbolize an object, action, or concept.

Icon comprehension	Refers to the perceptual and cognitive processes by which users interpret the meaning of an icon.
Icon interpretation enhanced with color	Refers to the manner in which color can highlight information and enhance drivers' interpretation of the icon.
Icon interpretation enhanced with shape	Refers to the manner in which the shape of an icon's outside edge or border can call attention to the hazard level being communicated.
Icon interpretation enhanced with text labels	Refers to the manner in which the content of text labels can affect the comprehension and interpretation of an icon.
Icon legibility	The reflection of the relationship between the driver, the icon, and the environment
Identification time task	After being shown slides of traffic signs (in both text and symbol format) and being asked to identify verbally the message that is being presented, the subject's response time is recorded as identification time.
Information units	Describe the amount of information presented in terms of key nouns and adjectives contained in a message.
ISO	International Organization for Standardization.
ITS	Intelligent Transportation Systems.
IVIS	In-Vehicle Information System.
LCD	Liquid crystal display.
Level of detail	Refers to the amount of detail necessary for recognition of a symbol.
Level of realism	Refers to the relationship between the portrayed object or concept and the graphic means used to represent that object or concept.
Luminance uniformity	Refers to the consistency of luminance values across an icon.

Matching Test	When the best or most appropriate design for a particular symbol has been determined, this test is used to examine how well that symbol will work within a set and whether the many symbols within the set can be discriminated from one another without confusion.
MUTCD	Manual on Uniform Traffic Control Devices.
Perceived urgency of auditory signals	Refers to the subjective impression of urgency that a signal gives to the person hearing it.
Perceptual principles of icon design	Refers to design recommendations based solely on the visual characteristics of the icon without reference to its intended function or meaning.
Production test	An icon evaluation approach in which a broad range of candidate symbols for a concept or referent (i.e., in-vehicle message) is generated. This approach is used when no symbols for a given message exist.
Prohibitive symbols	Icons that present a specific action and communicate that the action should be avoided.
Rating task	Determines the degree to which a symbol suggests or communicates its designated name.
Reaction time task	After a subject views a referent and then is shown a slide of one of the symbols, the subject is asked if they are the "same"; the amount of time the subject takes to make the response is recorded as reaction time.
Relationship between in-vehicle icons and roadway signs	Refers to the correspondence or consistency between these two forms of presenting information to the driver. Information might be presented on roadway signs alone, on the IVIS alone, or on both display media.
R&D	Research and Development.
SAE	Society of Automotive Engineers.

Selection of colors for coding visual displays	Refers to the use of different colors to either bring information to the attention of a driver or to aid the driver in distinguishing between items on a display. Color coding may be used to make absolute or relative discriminations, and should be used in a way that is redundant with other coding dimensions (e.g., shape, size, brightness).
Semantic differential method	After subjects rate symbols on 12 different adjective pairs, (e.g., weak-strong, strange-familiar), a factor analysis is performed to evaluate the results. A modified method uses adjective pairs more specific and relevant to designers (e.g., balanced-unbalanced, confusing-clear, etc.).
Sensory modality for presenting IVIS messages	Refers to the display modality most appropriate for presenting in-vehicle information to the driver. Almost all the literature on this topic suggests that operator performance can be improved by combining auditory and visual messages. These channels should be used together to provide either redundant or complimentary cues to the driver whenever possible. However, it is also important to know the advantages and disadvantages of using each of these modalities independent of one another so that when designers are faced with a choice, they can choose the modality that facilitates driver decision making and performance.
Simple tones	Auditory signals that present information through the use of single or grouped frequencies presented simultaneously.
Size of icon components	Refers to the visual angle subtended (at the driver's eye) in minutes of arc, by either the symbol or the text that comprises an icon.
SNR	Signal-to-Noise Ratio.
Speech messages	Auditory signals that present information through voice messages that add information beyond pure sound.
Symbol color	The perception of color is derived from variations in the wavelength or spectral composition of light. Color perception can be described in terms of three psychological dimensions: hue, saturation, and brightness. Hue is related to the dominant wavelength of the stimulus; saturation is somewhat more loosely related to the spectral bandwidth of the stimulus; and brightness is related to the luminance of the stimulus.

Symbol font	Refers to the geometrical characteristics or style of symbology. Design goals for symbol font are to avoid extensive flourishes and embellishments of the symbols.
Symbol height	Refers to the vertical distance between the top and bottom edges of a number or unaccented letter. Since IVIS devices can be used at a broad range of display distances, symbol height is best defined and specified as the visual angle subtended by the symbology (at the driver's eye) in minutes of arc.
Symbol spacing	Refers to the horizontal space between adjacent characters on a display. Symbol spacing is often expressed as the ratio of space-between-characters to symbol-height (space-to-symbol-height ratio).
Symbol strokewidth-to-height ratio	Refers to the ratio of the symbol stroke thickness to symbol height.
Symbol versus text presentation of IVIS messages	Refers to the style and format of in-vehicle visual messages. A key IVIS design issue is presenting information to the driver so that it is not distracting and is easily understood. Symbols or icons are increasingly used in the design of electronic devices under the assumption that they are preferable to text (e.g., "a picture is worth a thousand words"). However, if drivers are unfamiliar with the symbol or if the symbol is not intuitive, it may be less effective than a corresponding text message when used in an IVIS device.
Symbol width-to-height ratio	Refers to the ratio of the width to the height of the symbology.
Text labels	Words or phrases, as well as all other numerical and character symbols, provided as part of an icon that act to define, enhance, or clarify its meaning.
Timing of auditory navigation information	Refers to the time or distance at which the in-vehicle navigation system should present an auditory instruction to the driver before an approaching navigation maneuver (e.g., a required turn).

Types of icons	Refers to the classification of a particular icon based upon its resemblance to the message or referent.
UCS	Uniform Chromaticity Scale, a scale, wherein the units of color difference that are judged to be equally different, are separated by nearly equal distance.
User Interface design	Refers to the system design characteristics of a computer-based system that includes the screen layout and format, selection of icons, use of borders and windows, control selection and placement, and the procedures and "rules" that define transactions between the system and the user.
Visual angle	The angle formed by two rays of light, or two straight lines drawn from the extreme points of an object to the center of the eyes.
VDT	Visual Display Terminal.
VFD	Vacuum Fluorescent Displays.
Ways to use icons	Refers to the wide variety of options for using an icon to facilitate interaction with an in-vehicle information system (IVIS).
When to use icons	Refers to the criteria and issues that should be considered when determining whether an icon is the appropriate display element to use for an in-vehicle message.

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CHAPTER 14: REFERENCES

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CHAPTER 15: RELEVANT U.S. DEPARTMENT OF TRANSPORTATION, SOCIETY OF AUTOMOTIVE ENGINEERS, AND INTERNATIONAL ORGANIZATION FOR STANDARDIZATION DOCUMENTS

Reference No. ANSI Z535.2	**Title** *Environmental and facility safety signs*
Report Date June 3, 1998	
Number of Pages 22	**Author(s)** ANSI Accredited Standards Committee Z535 on Safety Signs and Colors, Subcommittee Z535-2: Environmental and Facility Safety Signs
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** American National Standards Institute (ANSI) **Organization Address** Washington, DC Headquarters 1819 L Street, NW, 6th Floor Washington, DC 20036 www.ansi.org

General Topic

Specifications for safety and warning signs and placards

Major Headings

- Safety sign colors and formats
- Sign design/layout
- Sign color specifications
- Symbols/pictorials
- Letter style and size
- Sign finish
- Sign placement
- Illumination

Summary

This standard establishes requirements for a uniform visual system of identification related to potential hazards in the environment. It provides for the design, application, and use of signs and placards employing this visual alerting system.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$46.00 US

Reference No. ANSI Z535.3	**Title** *Criteria for safety symbols*
Report Date April 9, 1998	
Number of Pages 48	**Author(s)** ANSI Z535 Committee on Safety Signs and Colors, Subcommittee Z535-3 on Criteria for Safety Symbols
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** American National Standards Institute (ANSI) **Organization Address** Washington, DC Headquarters 1819 L Street, NW, 6th Floor Washington, DC 20036 www.ansi.org

General Topic

This standard provides guidance in selecting symbols to alert people to hazards and to provide general safety messages.
Design specifications, development, and evaluation of symbols for use in safety and warning signs.

Major Headings

- Symbol types and colors
- Graphic design considerations
- Symbol selection criteria
- Symbol examples
- References
- Principles and guidelines for graphical design of hazard symbols
- General procedures for evaluating candidate symbols
- Symbol examples not meeting comprehension testing criteria for acceptance

Summary

This standard provides general criteria for the design, evaluation, and use of safety symbols to identify and warn against specific hazards, and to provide information to avoid personal injury.

Supplier IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	**Price** $90.00 US

Reference No. ANSI Z535.4	**Title** *Product safety signs and labels*
Report Date April 28, 1998	
Number of Pages 18	**Author(s)** ANSI Z535 Committee on Safety Signs and Colors, Subcommittee Z535-4 on Product Safety Signs and Labels
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** American National Standards Institute (ANSI)
	Organization Address Washington, DC Headquarters 1819 L Street, NW, 6th Floor Washington, DC 20036 www.ansi.org

General Topic

This standard provides guidance for manufacturers, employers, distributors, and others who have a desire to alert persons to potential personal injury hazard inherent in products.

Major Headings

- Sign classifications
- Sign or label format
- Safety sign and label colors
- Letter style and size
- Sign and label placement
- Expected life and maintenance
- Symbols/pictorials
- References
- Guidelines for increasing recognition of safety label components
- Principles and guidelines for the design of product safety signs and labels

Summary

This standard sets forth performance requirements for the design, application, use, and placement of safety signs and labels intended to identify potential hazards for people using, operating, servicing, or in proximity to, a wide variety of products. A product safety sign or label should alert people to a specific hazard, the degree of level of hazard seriousness, the probable consequence of involvement with the hazard, and how the hazard can be avoided.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$46.00 US

Reference No. BS AU 143f	**Title** *Specification for symbols for controls, indicators and tell-tales for road vehicles*
Report Date July 1999	
Number of Pages 20	**Author(s)** Technical Committee AUE/12, *Safety related to occupants*
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** British Standard Institute (BSI) **Organization Address** 389 Chiswick High Road London W4 4AL United Kingdom www.bsi.org.uk

General Topic

Standard symbols for vehicle instrumentation

Major Headings

- General
- Color
- Designation and illustration of symbols

Summary

This international standard establishes the symbols (conventional signs) for use on controls, indicators, and tell-tales of a road vehicle to ensure identification and facilitate use.

It also indicates the colors of possible optical tell-tales that inform the driver of either correct operation or malfunctioning of the related devices.

Note: Same as ISO 2575

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$116.00 US

Reference No.	Title
ETSI EG 201 013	*Definitions, abbreviations, and symbols*
Report Date	
April 1997	
Number of Pages	**Author(s)**
15	Human Factors Technical Committee of the ETSI
Type of Report	**Organization**
☒ Technical Report ☒ Guidelines ☐ Standard ☐ International Standard	European Telecommunications Standards Institute
	Organization Address
	F-06921 Sophia Antipolis Cedex France www.etsi.org

General Topic

Provides the preferred definitions of human factors related terms as well as keywords, abbreviations, and symbols in telecommunication human factors documents.

Major Headings

- Symbols

This ETSI Guide (EG) presents a list of the definitions, abbreviations, and symbols used in the documents prepared by the ETSI Technical Committee for Human Factors (TC-HF).

Summary

The purpose of this EG is to give guidance to TC-HF rapporteurs in the preparation of their documents, and to enhance the usability of these documents through the use of consistent terminology. The definitions, abbreviations and symbols given are not intended to be exclusive. Other definitions, abbreviations, and symbols different from those given here may be found in some TC-HF documents. However, the definitions in this technical report are generally to be preferred.

The intended users of this EG include:

- ETSI TC-HF
- Other ETSI TCs and STCs
- User groups

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$30.00 US

Reference No.	Title
ETSI EG 201 379	*Framework for the development, evaluation, and selection of graphical symbols*
Report Date	
December 1998	
Number of Pages	**Author(s)**
16	Human Factors Technical Committee of the ETSI
Type of Report	**Organization**
☐ Technical Report ☒ Guidelines ☐ Standard ☐ International Standard	European Telecommunications Standards Institute
	Organization Address
	F-06921 Sophia Antipolis Cedex France www.etsi.org

General Topic

Use and selection of graphical symbols

Major Headings

- Appropriate use of graphical symbols
- Selection of graphical symbols
- Development of new graphical symbols
- Evaluation

Summary

This document provides a framework for the development, evaluation, and selection of graphical symbols for application with telecommunications on terminals (on telecommunications equipment and for telecommunications functionality of human-computer interfaces, e.g. on keyboards and screens), within telecommunications services (e.g., to denote the availability of and access to a telecommunications service), as well as in printed materials (e.g., user guides and directories).

The document is applicable to relevant factors including:

- Appropriate use of graphical symbols
- Development of new graphical symbols for specific areas
- Evaluation of graphical symbols using the ETSI Multiple Index Approach (MIA)

Symbols for graphical programming or description languages are not included in the scope of this document.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$30.00 US

Reference No.	Title
ETSI ETR 070	*The Multiple Index Approach (MIA) for the evaluation of pictograms*
Report Date June 1993	
Number of Pages 23	**Author(s)** Human Factors Technical Committee of the ETSI
Type of Report ☒ Technical Report ☐ Guidelines ☐ Standard ☐ International Standard	**Organization** European Telecommunications Standards Institute **Organization Address** F-06921 Sophia Antipolis Cedex France www.etsi.org

General Topic

Describes the Multiple Index Approach (MIA) methodology used for the evaluation and adoption of new pictograms.

Major Headings

- Introduction
- Evaluating pictograms by multiple indices
- Structure of the MIA questionnaire
- Analysis
- Making a decision based on the results
- The special case of testing one pictogram set only
- Conclusion

Summary

This ETR describes the MIA method for evaluating pictograms. This method has been developed, tested, and employed in the context of an ETSI (TC Human Factors) study on pictograms for basic videophone functions and the examples given are taken from this study. This method has been found to be suitable as a general testing method for pictograms from all areas. The method described here takes the form of a questionnaire test, but it can be administered by other means as well (e.g., on a personal computer).

The main purpose of a pictogram evaluation study using MIA is to collect data and identify the best suited pictograms from a number of proposed pictograms.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$30.00 US

Reference No.	Title
ETSI ETR 113	*Results of an evaluation study of pictograms for point-to-point videotelephony*
Report Date	
October 1993	
Number of Pages	**Author(s)**
57	Human Factors Technical Committee of the ETSI
Type of Report	**Organization**
☒ Technical Report ☐ Guidelines ☐ Standard ☐ International Standard	European Telecommunications Standards Institute
	Organization Address
	F-06921 Sophia Antipolis Cedex France www.etsi.org

General Topic

Detailed report of an empirical evaluation study of pictograms for point-to-point videotelephony functions.

Major Headings

- General
- The ETSI study of pictograms for point-to-point videophone functions
- Method
- Results
- Discussion of the results
- The recommendation of pictograms for point-to-point videotelephony
- The post-test

Summary

This ETSI Technical Report (ETR) gives the results of an evaluation study of pictograms for basic videotelephony functions.

Seven pictogram sets, each containing candidate pictograms for the seven basic videophone functions, were empirically evaluated with the aim of identifying the most suitable pictogram set. Data for this study were collected in eight European countries from more than 650 respondents. The results of the study lead to the recommendation of a combined set of pictograms.

The Multiple Index Approach to the evaluation of pictograms is described in detail in ETR 070 (see page 14-9). The seven recommended pictograms are the content of ETS 300 375 (see page 14-11).

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$30.00 US

Reference No. ETSI ETS 300 375	**Title** *Pictograms for point-to-point videotelephony*
Report Date November 1994	
Number of Pages 18	**Author(s)** Human Factors Technical Committee of the ETSI
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** European Telecommunications Standards Institute **Organization Address** F-06921 Sophia Antipolis Cedex France www.etsi.org

General Topic

Specifications and standardized pictograms to ease the use of point-to-point videotelephony.

Major Headings

- Scope
- Normative references
- Definitions
- Pictograms for point-to-point telephony
- ETSI pictograms for the eight videophone functions

Summary

This ETS defines pictograms for representing eight point-to-point videotelephony functions.

1) Videophone / telephone
2) Videophone / camera on/off
3) Videophone / microphone on/off
4) Videophone / selfview on/off
5) Videophone / still picture on/off
6) Videophone / document camera on/off
7) Videophone / handsfree on/off
8) Videophone / loudspeaker on/off

Supplier IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	**Price** $30.00 US

Reference No. FMVSS 101	**Title** *Federal Motor Vehicle Safety Standards: Controls and displays —Passenger cars, multipurpose passenger vehicles, trucks and buses*
Report Date October 1, 2000	
Number of Pages 8	**Author(s)**
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** National Highway Traffic Safety Administration **Organization Address** Office of Vehicle Safety Compliance 400 7th Street SW Room 6111, Mail Code: NSA-30 Washington, DC 20590

General Topic

Specifications for the visibility of vehicle instrumentation

Major Headings

- Definitions
- Requirements
- Location
- Identification
- Illumination
- Conditions

Summary

This standard specifies requirements for the location, identification, and illumination of motor vehicle controls and displays.

The purpose of this standard is to ensure the accessibility and visibility of motor vehicle controls and displays and to facilitate their selection under daylight and nighttime conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task and by mistakes in selecting controls.

Supplier National Archives and Records Administration 700 Pennsylvania Ave, NW Washington, DC 20408 www.access.gpo.gov/nara/cfr/	**Price** N/A

Reference No.	Title
ISO 2575	*Road vehicles—Symbols for controls, indicators, and tell-tales*
Report Date	
March 15, 2000	
Number of Pages	**Author(s)**
41	Technical Committee ISO/TC 22: Road vehicles, SC 13: Ergonomics applicable to road vehicles
Type of Report	**Organization**
☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	International Organization for Standardization (ISO)
	Organization Address Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Standard symbols for vehicle instrumentation

Major Headings

- General
- Color
- Symbols and descriptions

Summary

This international standard establishes symbols (i.e., conventional signs) for use on controls, indicators, and tell-tales of a road vehicle to ensure identification and facilitate use.

It also indicates the colors of possible optical tell-tales that inform the driver of either correct operation or malfunctioning of the related devices.

Note: Also published under

- BS AU 143f (British Standards Institute)
- SAE 2042 (Society of Automotive Engineers)

Report date reflects most recent full draft

- Amendment 1 published March 22, 2001
- Amendment 4 published August 2, 2001

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$99.00 US

Reference No. ISO 3864	**Title** *Safety colours and safety signs*
Report Date March 1, 1984	
Number of Pages 14	**Author(s)** Technical Committee ISO/TC 80
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO) **Organization Address** Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Use of color in sign and symbol design

Major Headings

- Safety colors and contrast colors
- Geometric form and meaning of safety signs
- Design of graphic symbols
- Layout of safety signs
- Supplementary signs
- Colorimetric and photometric properties of materials
- Examples of safety signs

Summary

This international standard prescribes safety colors and safety signs for the purposes of preventing accidents and health hazards and meeting emergencies.

Supplier IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	**Price** $57.00 US

Reference No. ISO 7001	**Title** *Public information symbols*
Report Date February 1990	
Number of Pages 112	**Author(s)** Technical Committee ISO/TC 145: *Graphical symbols*
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO) **Organization Address** Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Catalog of public information symbols

Major Headings

- Numerical index and summary of public information symbols
- Compilation of single sheets

Summary

This international standard specifies the image content of graphical symbols used for the public information. The field of application specified for each graphical symbol is indicative of the way it is intended that the symbols should be used; their application may be extended into other fields where this is considered appropriate.

Report date reflects most recent full draft

- Amendment 1 published June 1993

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$111.00 US

Reference No.	Title
ISO 7239	*Development and principles for application of public information*
Report Date	
December 15, 1984	
Number of Pages	**Author(s)**
18	Technical Committee ISO/TC 145/SC 1: *Public information symbols*
Type of Report	**Organization**
☒ Technical Report ☐ Guidelines ☐ Standard ☐ International Standard	International Organization for Standardization (ISO)
	Organization Address
	Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Procedures for the development or adoption of public information symbols

Major Headings

- Development of public information symbols
- Visual design criteria
- Sign layout

Summary

This technical report recommends procedures to be followed and sets forth the essential technical criteria that should be taken into account when developing or considering the use of graphical symbols as a means of visual pictorial communication.

The field of application is mainly in public areas, but the recommendations of this technical report concerning visual design criteria can equally be applicable to perception problems in other areas where graphical symbols are used as the means of communication.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$67.00 US

Reference No.	Title
ISO/IEC 80461-1	*Basic principles for graphical symbols for use on equipment. Part 1: Creation of graphical symbols*
Report Date	
June 2001	
Number of Pages	**Author(s)**
31	IEC subcommittee 3C: *Graphical symbols for use on equipment*, of IEC technical committee 3: *Information structures, documentation and graphical symbols*
Type of Report	**Organization**
☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	International Organization for Standardization (ISO)
	Organization Address
	Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Creation of graphical symbols

Major Headings

- Symbol meaning
- Combination of graphical symbols
- Creation principles
- Basic pattern
- Application of symbol originals
- Creation procedure
- Designation systems

Summary

This multipart standard addresses the basic rules for creating graphical symbols for use on equipment, including line widths, form and use of arrows, negation elements, and use of the basic pattern that serves as a guideline for drawing equipment symbols. These design principles are required to be used for all graphical symbols on equipment; the standardized graphical symbols for which are found in ISO 7000 and IEC 60417.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$62.00 US

Reference No. ISO/IEC 80461-2	**Title** *Basic principles for graphical symbols for use on equipment. Part 2: Form and use of arrows*
Report Date July 15, 2001	
Number of Pages 7	**Author(s)** Technical Committee ISO/TC 145, *Graphical symbols*, and Technical Committee IEC/TC 3, *Documentation and graphical symbols*
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO) **Organization Address** Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Use of arrow in graphical symbols

Major Headings

- General principles
- Definitions of arrow forms and specific meaning
- Movement
- Speed and acceleration
- Special meaning of function and force
- Dimensions

Summary

This international standard addresses the basic rules for creating graphical symbols for use on equipment, including line widths, form and use of arrows, negation elements, and use of the basic pattern that serves as a guideline for drawing equipment symbols. These design principles are required to be used for all graphical symbols on equipment; the standardized graphical symbols for which are found in ISO 7000 and IEC 60417.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$39.00 US

Reference No.	Title
ISO 9186	*Graphical symbols—Test methods for judged comprehensibility and for comprehension*
Report Date	
April 1, 2001	
Number of Pages	**Author(s)**
36	Technical Committee ISO/TC 145: *Graphical symbols*, SC 1: *Public information symbols*
Type of Report	**Organization**
☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	International Organization for Standardization (ISO)
	Organization Address
	Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Methods to assess comprehensibility of graphical symbols

Major Headings

- Terms and definitions
- Procedures
- Tests using printed presentation
- Tests using computer screen presentation
- Accepting a variant as a standard graphical symbol
- Collection of information
- Comprehensibility judgments test
- Comprehension test
- Approved testing

Summary

This international standard specifies:

- The procedure to be used in gathering the information needed to request standardization of graphical symbols.
- The method to be used in testing which variant of a graphical symbol is judged the most comprehensible.
- The method to be used in testing the extent to which a variant of a graphical symbol communicates its intended message.

The purpose of this international standard is to ensure that graphical symbols, and signs using graphical symbols, are readily understood. It in no way ensures compliance with prohibitions or warnings using graphical symbols or symbol signs designed in accordance with this international standard.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$94.00 US

Reference No. ISO/IEC 11581-2	**Title** *Information technology—User system interfaces—Icon symbols and functions. Part 2: Object icons*
Report Date April 1, 2000	
Number of Pages 31	**Author(s)** Joint Technical Committee ISO/IEC JTC 1: *Information technology*, SC 35: *User interfaces*
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO) **Organization Address** Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Design of computer icons that represent objects

Major Headings

- Conceptual construction of object icons
- Object icon requirements and recommendations
- Icon specifications
- Minimum information to be given when submitting an icon

Summary

ISO/IEC 11581-2 applies to icons that are shown on a screen, that users can manipulate and interact with, and that represent data, or computer system functions. This part of ISO/IEC 11581 addresses only object icons. "Objects icons" is a term used in ISO/IEC 11581-2 to describe icons that represent functions by association with an object and that can be moved and opened. Other types of icons, listed in the foreword, are covered in other parts of the standard.

Annex A describes the information to be given when submitting new object icons for inclusion in this part of ISO/IEC 11581.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$73.00 US

Reference No. ISO/IEC 11581-6	**Title** *Information technology—User system interfaces—Icon symbols and functions. Part 6: Action icons*
Report Date February 1, 1999	
Number of Pages 20	**Author(s)** Joint Technical Committee ISO/IEC JTC 1: *Information technology*
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO)
	Organization Address Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Design of computer icons representing action

Major Headings

- Conceptual construction of action icons
- Action icon requirements and recommendations
- Action icon specifications

Summary

ISO/IEC 11581-6 applies to icons that are shown on a screen, that users can manipulate and interact with, and that represent data or computer system functions. This part of ISO/IEC 11581 addresses only action icons. Action icons represent actions by association with objects that prompt the user to recall the intended actions. This part of ISO/IEC 11581 describes user interaction with and appearance of action icons on the screen. Other types of icons listed in the foreword, are covered in other parts of the standard.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$57.00 US

Reference No. ISO/DIS 15008	**Title** *Road vehicles: Ergonomic aspects of transport information and control systems—Specifications and compliance procedures for in-vehicle visual presentation*
Report Date November 12, 2001	
Number of Pages 26	**Author(s)** Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics*
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** International Organization for Standardization (ISO) **Organization Address** Case postale CH-1211 Geneva 20 Switzerland www.iso.ch

General Topic

Visual characteristics of dynamic visual displays

Major Headings

- Specifications and measurement methods
- Design viewing position and illumination range
- Luminance contrast
- Color
- Alphanumerical character dimensions
- Pixel matrixes character format
- Reflections and glare
- Characteristics of presentation

Summary

This international standard gives minimum specifications for the image quality of displays that contain dynamic (changeable) visual information for road vehicle drivers from an on-board Transport Information and Control System (TICS) used while the vehicle is in motion, so that those displays are legible.

The specifications described in this standard are intended to be independent of display technologies. They address mainly the perceptual components and some basic cognitive components of the visual information (e.g., character legibility and color recognition). Other factors that affect performance and comfort (such as coding, format, and dialogue characteristics) are covered in other standards.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$53.00 US

Reference No.	Title
ITU-T F.910	*Procedures for designing, evaluating, and selecting symbols, pictograms, and icons*
Report Date February 1995	
Number of Pages 7	**Author(s)** ITU-T Study Group 1: Telecommunication Standardization Sector of ITU
Type of Report ☐ Technical Report ☒ Guidelines ☐ Standard ☐ International Standard	**Organization** International Telecommunication Union (ITU) **Organization Address** Place des Nations CH-1211 Geneva 20 Switzerland www.itu.int

General Topic

User-centered design and evaluation process for pictograms

Major Headings

- Methodology
- General parameters of experiments
- Other considerations

Summary

Various national, regional, and international standards organizations are responsible for the design, evaluation, and standardization of symbols, pictograms, and icons. To coordinate the work of these standards organizations, and to optimize the designs, it is desirable to follow a well-defined methodology. This recommendation describes a framework for a common methodology to be used by the ITU-T. To the extent that other standards organizations can work within this framework, the development of important designs should progress more rapidly. A uniform methodology will minimize duplication of effort and will maximize the relevance of collected data.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$25.00 US

Reference No.	Title
MUTCD	*Manual on Uniform Traffic Control Devices* (MUTCD)
Report Date June 2001	
Number of Pages	**Author(s)** National Committee on Uniform Traffic Control Devices
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** U.S. Dept. of Transportation, Federal Highway Administration (FHWA) **Organization Address** 400 7th Street, SW Washington, DC 20590

General Topic

Standard practices for traffic control and devices

Major Headings

- General provisions
- Guide signs
- Markings
- Highway traffic signals
- Low-volume rural roads
- Work zones
- Traffic controls for school areas
- Traffic controls for highway/rail grade crossings
- Traffic controls for bicycle facilities
- Traffic controls for highway/light rail transit grade crossings

Summary

Traffic control devices are defined as all signs, signals, markings, and other devices used to regulate, warn, or guide traffic and placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction.

The material described in this edition of the MUTCD provides the transportation professional with the information needed to make appropriate decisions regarding the use of traffic control devices on streets and highways. The material in this edition is organized to better differentiate between standards that must be satisfied for the particular circumstances of a situation, guidances that should be followed for the particular circumstances of a situation, and options that may be applicable for the particular circumstances of a situation.

Supplier	Price
American Traffic Safety Services Association 15 Riverside Parkway, Suite 100 Fredericksburg, VA 22406-1022	$100.00 US

Reference No. NATO STANAG 4050	**Title** *Standardization agreement: Symbols in designating function of controls in transport vehicles*
Report Date May 13, 1969	
Number of Pages 14	**Author(s)**
Type of Report ☐ Technical Report ☐ Guidelines ☐ Standard ☒ International Standard	**Organization** North Atlantic Treaty Organization (NATO) **Organization Address** NATO Headquarters Blvd Leopold III 1110 Brussels, Belgium natodoc@hq.nato.int

General Topic

Standardization of transport vehicle control instrumentation

Major Headings

- Contours for functional categories
- System of symbols designed to replace or supplement the text of instruction plates and forms for transport vehicles

Summary

The object of this agreement is to standardize symbols to replace lettering on controls in transport vehicles for the NATO Armed Forces.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$31.00 US

Reference No. SAA ADR 18/02	**Title** *Instrumentation*
Report Date December 1998	
Number of Pages 5	**Author(s)**
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** Department of Transport and Regional Services: Land Transport **Organization Address** GPO Box 594 Canberra ACT 2601 Australia www.dotrs.gov.au

General Topic

Specifications for location and visibility of passenger vehicle visual indicators

Major Headings

- Visual indicators
- Location of visual indicators
- Visibility of visual indicators
- Speedometers and odometers

Summary

The function of this national standard is to specify requirements for the provision and location of certain "visual indicators." It also specifies requirements for speedometers and odometers.

Supplier	**Price**
ADR Subscriptions Vehicle Safety Standards Dept. of Transport and Regional Services GPO Box 594 Canberra ACT 2601 Australia	$21.40 AU (for entire ADR CD-ROM)

Reference No.	Title
SAA AS 2342	*Development, testing, and implementation of information and safety symbols and symbolic signs*
Report Date	
October 12, 1992	
Number of Pages	**Author(s)**
40	Committee MS/3, *Public Information Symbols*
Type of Report	**Organization**
☐ Technical Report	Standards Association of Australia (SAA)
☐ Guidelines	**Organization Address**
☒ Standard	1 The Crescent Homebush, NSW 2140 Australia
☐ International Standard	

General Topic

Development, evaluation, and adoption of symbol signs

Major Headings

- Determination of need for a symbol and establishment of design criteria
- Selection and testing of graphic symbols and symbolic signs
- Principles for the design of graphic symbols
- Principles for the design of signs incorporating symbols
- Siting and maintenance
- Establishment of need for a graphic symbol or symbolic sign
- Method of collection and appropriateness assessment of symbol and symbol sign variants for comprehension and related testing
- Comprehension and recall tests
- Photometric and colorimetric properties of sign materials
- Sources of potential test symbols

Summary

This standard specifies principles and procedures for determining the need, selection, testing, and design of graphic symbols for:

a. Equipment or parts of equipment to instruct or advise people handling the equipment as to its use and operation;

b. Locations where people may work, assemble, or move, to give them information or instructions, such as prohibitions, warnings, rules, limits, or directional guidance; or

c. Pictorial representations on maps, plans, drawings, illustrations, and similar documents.

It also specifies principles and procedures for the design and use of information and safety signs using these symbols.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$33.00 US

Reference No.	Title
SAA AS 2899.0	*Public information symbol signs—Consolidated index*
Report Date	
September 5, 1986	
Number of Pages	**Author(s)**
13	Committee MS/3, *Public Information Symbols*
Type of Report	**Organization**
☐ Technical Report	Standards Association of Australia (SAA)
☐ Guidelines	**Organization Address**
☒ Standard	1 The Crescent Homebush, NSW 2140 Australia
☐ International Standard	

General Topic

Numerical index for standardized information signs

Major Headings

- Numerical Index

Summary

This standard lists the referents for standard public information symbol signs and gives the function and fields of application for each sign. It also defines terms used in this standard and on the single sheets in:

AS 2899.1 General Information Signs
AS 2899.2 Water Safety Signs
AS 2899.3 Hospital Signs
AS 2899.4 Signs for the Working Environment

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$25.00 US

Reference No.	Title
SAA AS 2899.1	*Public information symbol signs—General information signs*
Report Date	
September 5, 1986	
Number of Pages	**Author(s)**
53	Committee MS/3, Public Information Symbols
Type of Report	**Organization**
☐ Technical Report	Standards Association of Australia (SAA)
☐ Guidelines	**Organization Address**
☒ Standard	1 The Crescent Homebush, NSW 2140 Australia
☐ International Standard	

General Topic Single sheets for general information signs

Major Headings

- General information signs

Summary

This standard includes black-and-white single sheets for general information signs.

Note: Many symbols are the same as those described in ISO 7001.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$33.00 US

Reference No. SAE ARP 4155-A	**Title** *Human interface design methodology for integrated display symbology*
Report Date October 1997	
Number of Pages 19	**Author(s)** SAE Subcommittee G-10I, *Symbology for Electronic Displays* of the SAE Committee G-10, *Aerospace Behavioral Engineering Technology*
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** Society of Automotive Engineers, Inc. (SAE)
	Organization Address SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Design methodology for development of symbology

Major Headings

- Background
- Design methodology

Summary

This standard describes a recommended design approach that emphasizes the fundamental relationship between symbols, the information they encode, the context within which the symbols are displayed, and the tasks being supported. While this document is aimed at aircraft displays involving dynamic control or monitoring tasks, the methodology is applicable to a wide range of symbology development situations.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$77.00 US

Reference No.	Title
SAE ARP 577-C	*Emergency placarding—Internal and external*
Report Date	
March 16, 1993	
Number of Pages	**Author(s)**
7	SAE Committee S-9, *Cabin Safety Provisions*
Type of Report	**Organization**
☐ Technical Report ☒ Guidelines ☐ Standard ☐ International Standard	Society of Automotive Engineers, Inc. (SAE)
	Organization Address
	SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Specifications for the design of aircraft emergency placards

Major Headings

- Information presentation
- Written instructions
- Pictorial instructions
- Minimum-sized pictures and words
- Color of placard and background
- Location
- Warnings

Summary

This SAE Aerospace Recommended Practice (ARP) provides criteria for the development and standardization of placards containing easily understood signs, symbols, and/or instructions for locating and operating exits and emergency equipment that might be used or operated by cabin occupants and rescue personnel under emergency conditions. In addition, this ARP gives guidance in the selection and development of warning labels. The placards are intended to be seen and understood by occupants inside and, in the case of external exit placards, by persons outside the airplane.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$50.00 US

Reference No. SAE J1048	**Title** *Symbols for motor vehicle controls, indicators and tell-tales, standard*
Report Date March 1980	
Number of Pages 16	**Author(s)** SAE Human Factors Engineering Committee
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** Society of Automotive Engineers, Inc. (SAE) **Organization Address** SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Standardized symbols for vehicle instrumentation

Major Headings

- Designation and illustration of symbols

Summary

This standard specifies the symbols, that is, conventional signs, with which certain controls, indicators and tell-tales of a road vehicle are to be provided to ensure their identification and facilitate their utilization.

It also indicates the colors of possible optical tell-tales, which warn the driver of the operation or malfunctioning of the devices and equipment connected to the corresponding controls.

This standard is applicable to those controls that are fitted on the instrument panel, or in the immediate vicinity of the driver.

Supplier	**Price**
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$50.00 US

Reference No.	Title
SAE J115	*Safety signs*
Report Date	
February 1995	
Number of Pages	**Author(s)**
10	SAE Human Factors Technical Committee SC2 – *Machine Displays and Symbols*
Type of Report	**Organization**
☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	Society of Automotive Engineers, Inc. (SAE)
	Organization Address
	SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Guidelines for signage symbols

Major Headings

- Sign format
- Letter style and size
- Sign placement
- Expected life and maintenance
- Pictorials
- Guidelines for creating pictorials

Summary

This SAE standard establishes signal words, color combinations, letter sizes, and durability requirements for permanently and temporarily affixed safety signs for off-road, self-propelled work machine categories of construction, general purpose industrial, forestry, agricultural tractors, and specialized mining machinery as defined in SAE J1116. This document is suitable for application to tools, machines, and machinery used in the specified categories.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$77.00 US

Reference No. SAE J1362	**Title** *Graphical symbols for operator controls and displays on off-road self-propelled work machines*
Report Date July 1997	
Number of Pages 81	**Author(s)** SAE Human Factors Technical Committee SC2: *Machine Displays and Symbols*
Type of Report ☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	**Organization** Society of Automotive Engineers, Inc. (SAE)
	Organization Address SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Standardized symbols for off-road machinery

Major Headings

- Symbol
- General
- Color
- Development of new symbols
- Standardized symbology
- Guidelines for development and evaluation of graphical symbols

Summary

SAE J1362 presents graphical symbols for use on operator controls and other displays on construction, general-purpose industrial, agricultural, forestry, and specialized mining categories of off-road self-propelled work machines, as defined in SAE J1116. Symbols for agricultural equipment other than the basic agricultural tractor (for example, combine harvesters, cotton harvesters, forage harvesters, balers, and sprayers) are covered by ASAE S304 and are therefore excluded from the scope of SAE J1362.

Supplier IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	**Price** $101.00 US

Reference No.	Title
SAE J2217	*Photometric guidelines for instrument panel displays that accommodate older drivers*
Report Date	
October 1991	
Number of Pages	**Author(s)**
6	SAE Mature Driver Standards Committee
Type of Report	**Organization**
☒ Technical Report ☐ Guidelines ☐ Standard ☐ International Standard	Society of Automotive Engineers, Inc. (SAE)
	Organization Address
	SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Provides introductory information that should be considered when setting photometric guidelines for instrument panel displays that are designed to accommodate the older driver.

Major Headings

- Luminance contrast
- Color usage
- Color preference
- Brightness preference
- Gloss

Summary

Physical parameters that influence the legibility of an instrument panel display include: letter/graphic size; the luminance and color difference between graphics and background; the observer's luminance adaptation level; and the level of the glare present. Several aspects of visual functioning deteriorate as part of the normal aging process. These include: a reduction in luminance and color-contrast sensitivity; an increase in sensitivity to glare; a reduction in visual accommodation capacity; and a reduction in the sensitivity to light. This SAE information report provides introductory information that should be considered when setting photometric guidelines for instrument panel displays that are designed to accommodate the older driver.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$50.00 US

Reference No.	Title
SAE J2402	*Road vehicles: Symbols for controls, indicators, and tell-tales*
Report Date	
June 1997	
Number of Pages	**Author(s)**
18	SAE Controls and Displays Standards Committee
Type of Report	**Organization**
☐ Technical Report ☐ Guidelines ☒ Standard ☐ International Standard	Society of Automotive Engineers, Inc. (SAE)
	Organization Address
	SAE World Headquarters 400 Commonwealth Drive Warrendale, PA 15096-0001 www.sae.org

General Topic

Standard symbols for vehicle instrumentation

Major Headings

- General
- Color
- Designation and illustration of symbols

Summary

This SAE standard establishes the symbols (i.e., conventional signs) for use of controls, indicators, and tell-tales of a road vehicle to ensure identification and facilitate use. It also indicates the colors of possible optical tell-tales that inform the driver of either correct operation or malfunctioning of the related devices.

Note: Same as ISO 2575.

Supplier	Price
IHS Global Engineering Documents 15 Inverness Way East Englewood, CO 80112 global.ihs.com	$77.00 US

CHAPTER 16: INDEX

Bold indicates glossary definition.

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