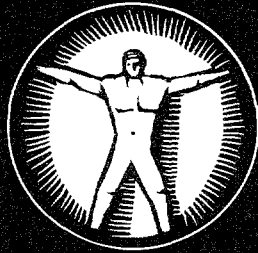


TECHBRIEF



Researchers at the Human Centered Systems Laboratories test and evaluate driver performance using a wide range of testing facilities. Researchers examine a variety of geometric and operational issues, as well as the effects of these elements on drivers and pedestrians.



U.S. Department of Transportation
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General Development Process for In-Vehicle Icons

Report No. FHWA-RD-03-065 and FHWA-RD-03-063

Introduction

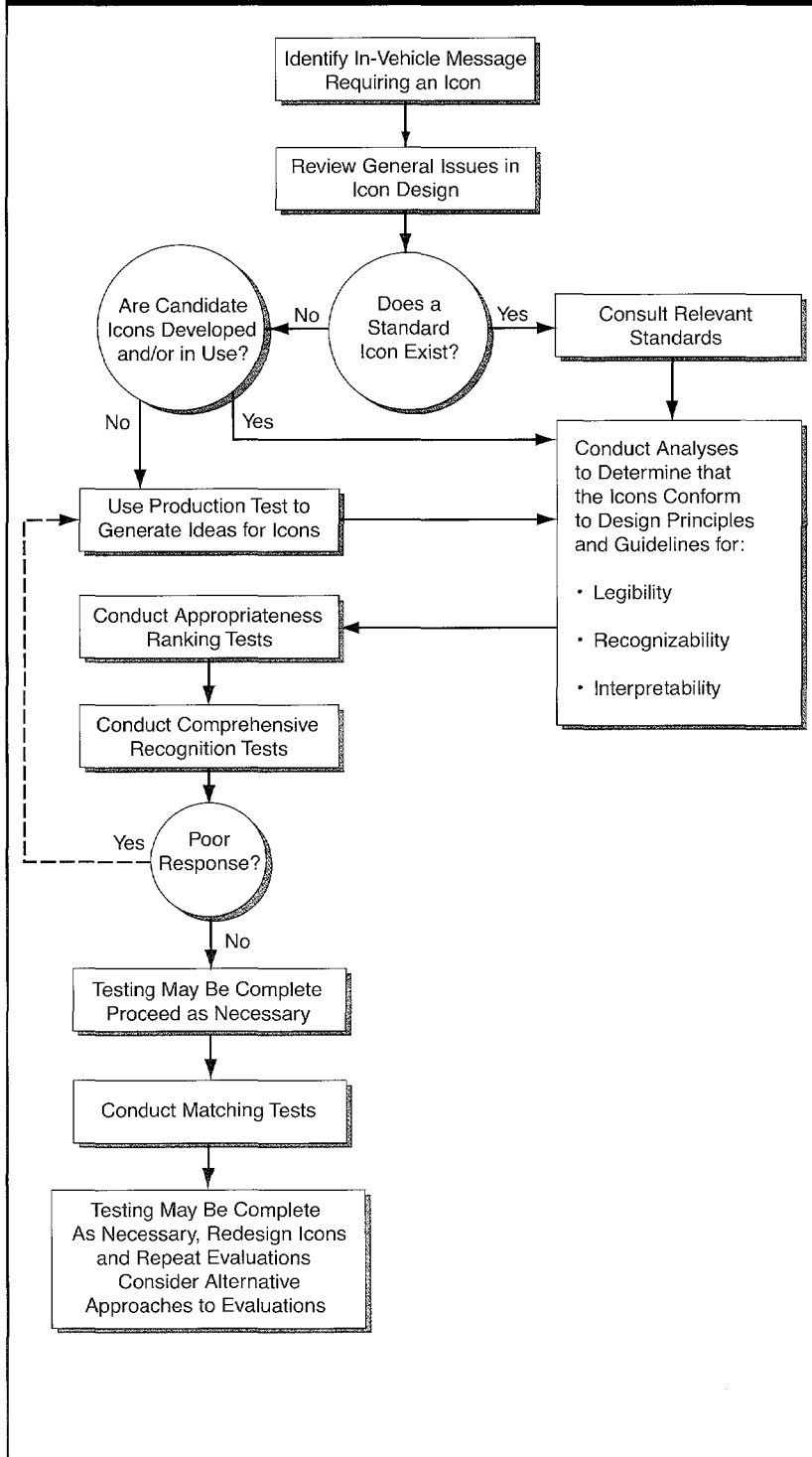
This research update describes a general process for developing in-vehicle icons. It reflects a subset of the results of a Federal Highway Administration project to develop a set of clear, concise, and user-centered human-factors design guidelines for in-vehicle icons. A project working group, comprising more than 30 representatives experienced in icon design, intelligent transportation systems (ITS), and human factors, has provided expertise; helping to ensure that the resulting design guidelines conform to icon designers' specific needs with respect to content, organization, and format.

Icons are visual representations or images used to symbolize an object, action, or concept, and are among the oldest forms of communication. They provide several advantages over a text-only approach, including quick and accurate recognition, presentation in a smaller area, and information conveyance across many languages and cultures.

Despite the obvious applicability of icons to the design of ITS, such as advanced traveler-information systems (ATIS) and collision-avoidance systems (CAS), poorly designed icons can lead to driver confusion and errors, and actually exacerbate existing traffic problems. Icons are used widely, but few guidelines exist that can be confidently used by vehicle and electronics designers during icon development. The lack of guidelines, standards, and a systematic framework to aid icon design has resulted in: design by consensus for many ITS-related icons; a lack of scientific rigor in icon development; non-intuitive and difficult-to-learn icons for in-vehicle messages; and multiple icons for the same message.

This research update describes how to design and evaluate in-vehicle icons. The process outlined in figure 1 provides a framework for icon design that has been organized and used by the International Organization for Standardization (ISO) and is consistent with good design and evaluation practices. The empirical portions of the guidelines have been suggested in

Figure 1. General development process for in-vehicle icons



a number of data sources, while the analytical aspects are consistent with several comprehensive sources in the icon development domain. This update also emphasizes three components of the general icon-development process: general effectiveness, recognizability, and conducting comprehension tests.

General design principles for in-vehicle icons provide important information that will increase icons' effectiveness and utility. 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, or driver workload in selecting icons. That is, using general design principles alone cannot assess specific effectiveness with the potential user group. 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.

Human Factors Design Guidelines to Increase Icon Effectiveness

A review of some general icon design issues (second box in figure 1) reveals two factors

critical to icon development: a basic understanding of what icons are, as well as general procedures that can be used during icon design to maximize their effectiveness when used by the driving public. Of the 42 design guidelines produced for this project, an entire chapter (6 guidelines) has been devoted to such basic design issues. Design guidelines associated with three general aspects of icon design are summarized below, reflecting key design questions such as: 1) when should icons be used, 2) what kinds of icons are there, and 3) what are key components of an icon?

When should icons be used?

A critical element of icon design is understanding the criteria and issues to consider when determining whether an icon is appropriate to display an in-vehicle message. Figure 2 shows some examples of the appropriate use of icons. Although all icons should be tested and evaluated before final implementation in vehicles, icons generally should be used in place of text when:

- Quick and accurate recognition of a message is necessary (e.g., warnings).
- Visual or spatial concepts are displayed (e.g., augmented signage).

- The driver will be performing a visual search of options (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.
- An icon already exists and has a generally accepted meaning.

What types of icons can be used?

Icons can be classified based on their resemblance to a particular in-vehicle message or referent. Icons can fall into one of three categories; examples and summaries of these three categories are presented in

Figure 2. Examples of the appropriate use of icons













Icon Design	Do This...	...Not This
Quick and Accurate Recognition is Necessary		
Displaying Visual or Spatial Concepts		
Presenting a Set of Alternatives	   	   

figure 3. Importantly, these three different types of icons have different implications for icon development and design.

Type 1. Image-related icons are graphic representations of the object or act they represent. Image-related icons are directly comprehended and should be used whenever possible.

Type 2. Concept-related icons are based on an example or property of a real object or action. Concept-related icons can be used if the user can be expected to comprehend the context in which the icon is presented.

Type 3. Arbitrary icons do not resemble the object or action they represent, but become

meaningful only through convention and education. Arbitrary icons can be difficult to recognize, hard to learn, and hard to remember. They should be used only if the user understands the context in which they will be presented and also possesses the specialized knowledge required to understand them.

What are the different parts of an icon and how can they be designed to maximize icon effectiveness?

Icons are complex visual images with several parts. Through careful design, these different parts can work together to increase the likelihood that drivers will comprehend the icon.

Figure 4 summarizes the key components of an icon. Table 1 presents human factors design guidelines associated with each component.

Human-Factors Evaluation Procedures for Icons

Evaluating icons is a process to determine whether an icon, or an integrated set of icons, meets specific criteria for 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 implementing the icon in the in-vehicle environment will improve driving and system performance and

Figure 3. Types of icons



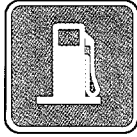






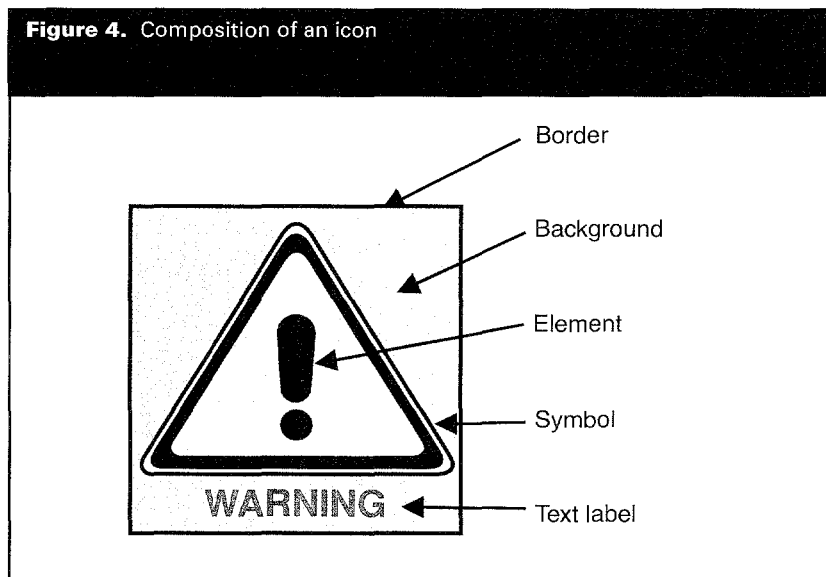
Icons	Key Examples	Other Examples
Image Related	 <p>Fasten Seatbelt</p>	 <p>Telephone Ahead</p>  <p>Gas Station Ahead</p>
Concept Related	 <p>Flash Function on a Camera or High Voltage Symbol in a Power Plant</p>	 <p>Curve Signs</p>  <p>Elevator</p>
Arbitrary	 <p>Addition Symbol, First Aid Symbol, or International Symbol for the Red Cross</p>	 <p>U.S. Postal Service</p>  <p>Medical Profession</p>

Table 1. Design guidelines for icon components

Icon Component	Human-Factors Design Guidelines
Border	<ul style="list-style-type: none"> • Can be used to frame the entire icon (top, bottom, and sides).
Background	<ul style="list-style-type: none"> • Do not 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	<ul style="list-style-type: none"> • Use commonly accepted or standardized elements when possible. • Elements should reflect good design principles.
Symbol (Shapes)	<ul style="list-style-type: none"> • Circles should be used for presenting prohibition or mandatory information. • Triangles or diamonds should be used to present warning or cautionary information. • Squares or rectangles should be used to present general information, instructions, or safe condition information.
Text Label	<ul style="list-style-type: none"> • Use only when necessary, but especially when the icon is concept-related or arbitrary. • Keep text to no more than two or three words.

Figure 4. Composition of an icon



not degrade driver safety. Figure 5 expands upon figure 1, and provides a more detailed set of evaluation procedures.

Two aspects of evaluation—recognizability principles and comprehension testing—are elaborated below.

Recognizability Principles

As mentioned in figure 5, candidate icons must be analyzed to determine whether they conform to design principles

and guidelines for legibility, recognizability, and interpretability. Icon recognition reflects the relationships among the driver, the icon, and other icons or visual display elements. Icon recognition will depend on design issues such as the shape of the icon, figure/ground relationships, level of detail, use of overlapping elements, and discriminability from other symbols. (As stated above, of the 42 design guidelines produced for this project, 6 are devoted to icon recognition). In this document, design guidelines associated with three areas that influence recognition of icons are summarized, reflecting key design questions such as: 1) what basic principles of perception can be used to increase icon recognition, 2) what is the appropriate level of detail for in-vehicle icons, and 3) what is the appropriate level of realism for in-vehicle icons?

What basic principles of perception can be used to increase icon recognition?

Many perceptual principles about how we decode and comprehend symbols come from the ideas and experiments of Gestalt psychologists around the turn of the last century. These perceptual principles reflect the notion that the structural properties of symbols and icons are important determinates of their perceptibility and, hence, recognition and usefulness. Figure 6 highlights some of these principles.

Figure 5. Evaluation procedures for in-vehicle icons

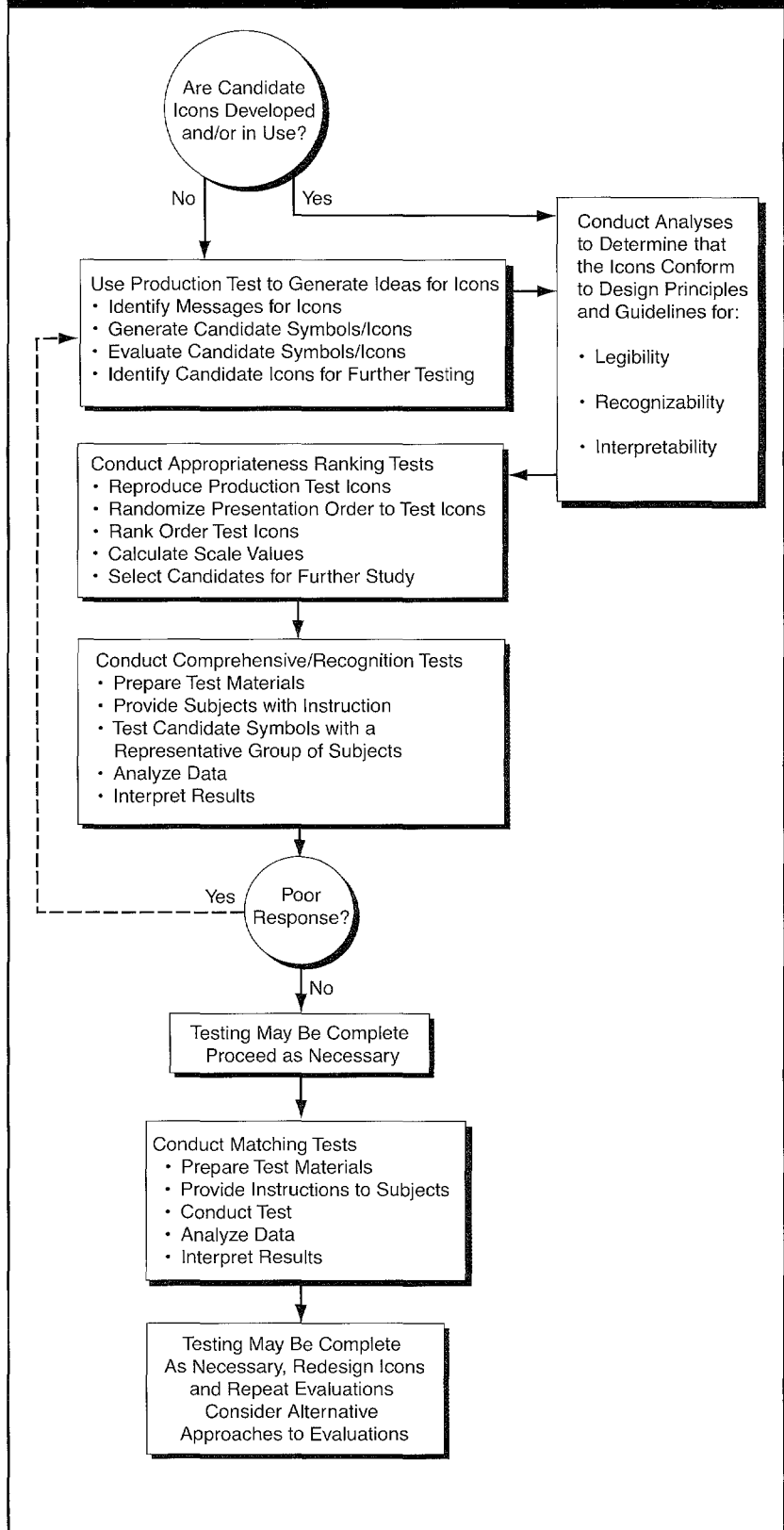

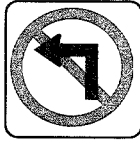





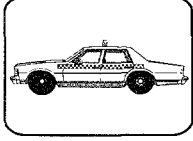




Figure 6. Key perceptual principles for icon design

Icon Design Parameter	Recommendation	...Do This	...Not This
Figure/Ground Relationship	Emphasize a clear, stable, and solid relationship between a symbol and its background		
Figure Boundaries	Solid shapes are better than thin-line or dotted-line boundaries (unless the element in question is depicting action or movement)		
Closure	Use closed figures instead of figures with discontinuous lines, outlines, or disjointed elements		
Simplicity	Icons should be simple with only the necessary detail included		
Unity	All parts of the symbol should be enclosed within a single boundary		

What is the appropriate level of detail for in-vehicle icons?

Only details (see figure 7) that will add to the meaning of an icon or symbol should be included; those that distract from the true goals of recognition and comprehension should be omitted. Key human-factors design guidelines for determining level of detail for icons are:

- Design symbols on a 20 x 20 unit grid, making sure that no significant detail is smaller in size than 1 square unit.

- Significant details within a symbol should subtend 3 degrees of visual angle (minimum).
- Line thickness for a significant detail should subtend 2 degrees of visual angle (minimum).

What is the appropriate level of realism for in-vehicle icons?

Level of realism refers to the style in which a symbol is drawn. Deciding whether to use a detailed, realistic style or

a simplified style can have a great impact on the recognizability of symbols. Including detail in the design of some symbols and icons can make them easier to recognize, while adding it to others can make it harder. Figure 8 presents some design guidelines and examples of the appropriate level of realism for in-vehicle icons (Horton, 1994. *The Icon Book: Visual Symbols for Computer Systems and Documentation*. New York: J. Wiley & Sons).

Comprehension Testing

Well-defined criteria are used to identify the extent to which the perceived meaning matches the intended meaning for a representative sample of drivers. Data or results from this process are analyzed to assess drivers' comprehension of the symbol or icon. These data can provide guidance in the design of in-vehicle symbols or icons.

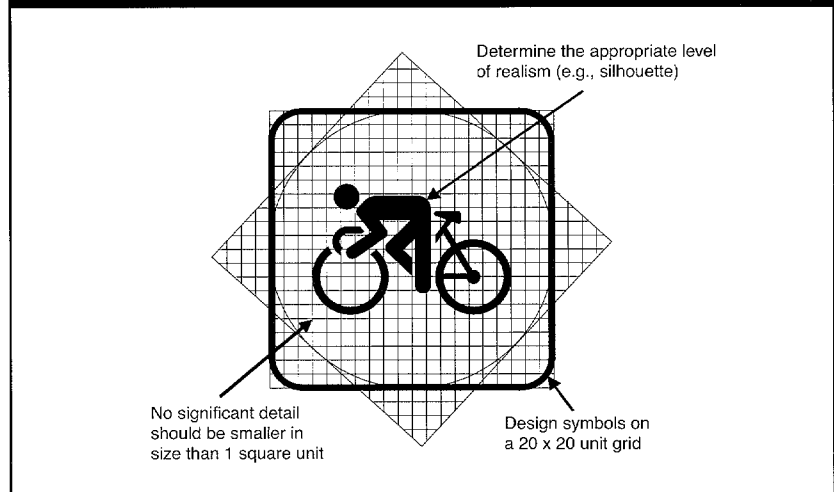
Comprehension testing is only part of a comprehensive, systematic approach for icon development and evaluation. Comprehension tests can be preceded by production tests (see figure 5) to screen candidate icons for comprehension testing. Comprehension tests can be followed by a matching test to determine how well individual symbols work within a set of symbols.

Steps for Comprehension Testing

Step 1: Prepare for comprehension testing:

- Prepare test materials.
 - Prepare icons so they are as similar as possible, in terms of size, appropriate color, resolution, etc., to the future production application.
 - Place candidate icons on separate sheets of paper, slides, or computer screens, depending on the presentation method planned for the study.
 - Test some standard icons in addition to the candidate

Figure 7. Example of appropriate level of detail



icons to provide comparison data. Approximately 10-15 percent of the total icons tested should be common, standard in-vehicle icons (such as seatbelt, oil pressure, and temperature icons).

- Randomize presentation order across subjects.
- Separate different candidates for the same message into distinct test sets.
- Prepare and provide subjects an example sheet with a common icon (like a fuel pump to indicate a fuel gauge) and its meaning written beneath the graphic.
- Develop context statements.
- Schedule 30-40 test subjects.
 - All subjects should be licensed drivers who drive at least twice a month.
 - The goal for subject population is an approximately equal mix of older/younger, male/female subjects. “Younger” subjects are

typically ages 18-30, while “older” subjects are typically ages 55-75.

- In general, subject groups should be as representative as possible of the larger driving population; diverse backgrounds and fields of study are preferred.
- Testing typically is done with groups of 10-20 subjects to increase the overall efficiency of individual sessions.

Step 2: Conduct comprehension testing:

- Provide subjects with instructions and examples.
 - Indicate the context in which the icon will be used. In real-world driving, in-vehicle icons are presented in the context of certain in-vehicle capabilities and driving circumstances; thus evaluations should include a description of the context in which they will be presented and used. 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 extremes should be avoided. The context provided to subjects should describe the: 1) general capabilities of the in-vehicle information system or technology 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.

- Ask subjects to write down the action, condition, activity, location, etc., associated with the icon (e.g., "What do you think this icon means?").
- Test candidate symbols with a representative group of subjects.
- Present test subjects with candidate icons and ask them to write down the

Figure 8. Five levels of icon realism (Horton, 1994)



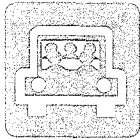


Example	Level of Realism	Design Style	When to Use
	Photographic Realism	Photographs and Photographic Drawings	Use for presenting complex symbols with a lot of detail (e.g., specific items, people, buildings, or landmarks)
	Simplified Drawing	Outline with Distinct Interior Details	Use for presenting complex symbols with small significant parts, especially when the objects have similar profiles (e.g., mechanical or electrical devices)
	Caricature	Exaggeration of Crucial Details	Use for presenting symbols that have a small, crucial feature or for simplifying complex details
	Outline	Outline with Only Prominent Details	Use for presenting small symbols that represent a familiar object with a distinct profile
	Silhouette	Shape Filled with Solid Color Contrasting with Background	Use 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

Table 2. Rating scales for categorizing and scoring subjects' responses to the icons

Comprehension Score Category	Description
1	The response matches the intended meaning of the icon exactly.
2	The response captures all major informational elements of the intended meaning of the icon, but is missing one or more minor informational elements.
3	The response captures some of the intended meaning of the icon, but it is missing one or more major informational elements.
4	The response does not match the intended meaning of the icon, but it captures some major or minor informational elements.
5	The response does not match the intended meaning of the icon, but it is somewhat relevant.
6	Participant's response is in no way relevant to the intended meaning of the icon.
7	Participant indicated he/she did not understand the icon.
8	No answer.
9	For safety-critical icons only, the response indicates that the participant perceived the message to convey the <i>opposite action</i> as that intended by the icon.

action, condition, activity, location, etc., that they believe the icon represents.

Step 3: Analyze comprehension data and summarize results:

- Analyze data.
 - At least two trained judges categorize responses along a scale according to well-defined criteria that identify the likelihood that an individual response indicates correct comprehension of the icon. That is, the perceived meaning should be compared to the intended meaning. Table 2 below should be used to categorize responses. For each icon candidate, convert the total number of responses in each category into percentages.
 - During the scoring process, judges should maintain a detailed score sheet of the subjects specific responses assigned to each of the nine comprehension score categories for each icon tested. These can be provided to the organization that originally submitted the icons for comprehension testing.
 - Of the 9 scoring categories in table 2, scores for 1 or 2 are the most important, as they—when summed—define overall comprehension rates. The remaining scores (particularly 3, 4, 5, and 9) are most useful for diagnostic purposes (i.e., identifying problems with candidate icons and possible improvements).
 - For safety-critical icons that demand immediate driver action, identify the number and percentage of critical confusions or errors (category 9).
- Interpret and summarize results.
 - Decisions regarding criteria for minimum percent correct comprehension rates for individual icons should reflect designers' needs, as well as the consequences associated with selecting a cutoff that is too high or too low. ISO requirements for an acceptable symbol have been a (minimum) 66 percent correct comprehension level (i.e., combined categories 1 and 2 from table 2), while the American

National Standards Institute (ANSI) specifies that 85 percent correct comprehension should be used. ANSI specifies that more than 5 percent critical confusions (with a sample of at least 50 participants) should result in rejection of the icon.

- The distribution of responses across the nine score categories should be taken into consideration as

well. For example, consider a situation where Candidate Icon A obtains the following distribution of rating scores across the 9 categories: 1–2: 30 percent; 3–4: 5 percent; 5–8: 65 percent; 9: 0 percent; and Candidate Icon B obtains the following distribution of rating scores across the 9 categories: 1–2: 30 percent; 3–4: 65 percent; 5–8: 5 percent; 9: 0 percent. Although

the “correct comprehension” rate (combined scores of rating score categories 1 and 2) for the two icons is the same at 30 percent, it is clear that comprehension of Icon B was better, and that Icon B likely will need less revision for an increase in the number of subject responses that fall into either category 1 or category 2 from table 2.

Summary

This TechBrief provides highlights from a project conducted to develop a set of clear, concise, and user-centered human-factors design guidelines for in-vehicle icons. In addition, the project also developed an interactive design tool for presenting individual candidate icons in the icon collection in a manner that also provides evaluative information about the icons. This design tool, Icon IDEA (Icon Interactive Development and Evaluation Assistant), provides designers with the following basic functions:

- A searchable database of more than 400 candidate icons, organized and selectable by specific in-vehicle system functions and intended messages.
- Access to evaluation ratings for each of the icons in the database that reflect critical physical features of the icons such as: adherence to perceptual principles, use of text, color, level of detail, and realism.
- Comprehension ratings from experimental subjects for a subset of the icons.
- Recommendations for further refining the design of an icon following the physical feature evaluation.
- Clear and simple design guidelines for developing and evaluating in-vehicle icons.

The development of this automated tool to assist with creating and evaluating icons will help in-vehicle designers in two ways. First, it will substantially improve the initial recognition and usability of icons being considered for use inside the vehicle. Second, because the initial icons will be of higher quality, the time from icon conceptualization to implementation will be decreased.

Additional information may be found in:

In-Vehicle Display Icons and Other Information Elements: Final In-Vehicle Symbol Guidelines. Federal Highway Administration, FHWA-RD-03-065, 2003.

In-Vehicle Display Icons and Other Information Elements: Final Report. Federal Highway Administration, FHWA-RD-03-063, 2003.

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Research—The principal investigator for this research study was Dr. John Campbell, Battelle Human Factors Transportation Center, 4500 Sand Point Way NE, Suite 100, Seattle, WA, 98105-3949, 205-528-3254, Contract #DTFH61-97-C-00061.

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This RD&T TechBrief summarizes an experiment, its results, data collected from analysis, or findings and recommendations.