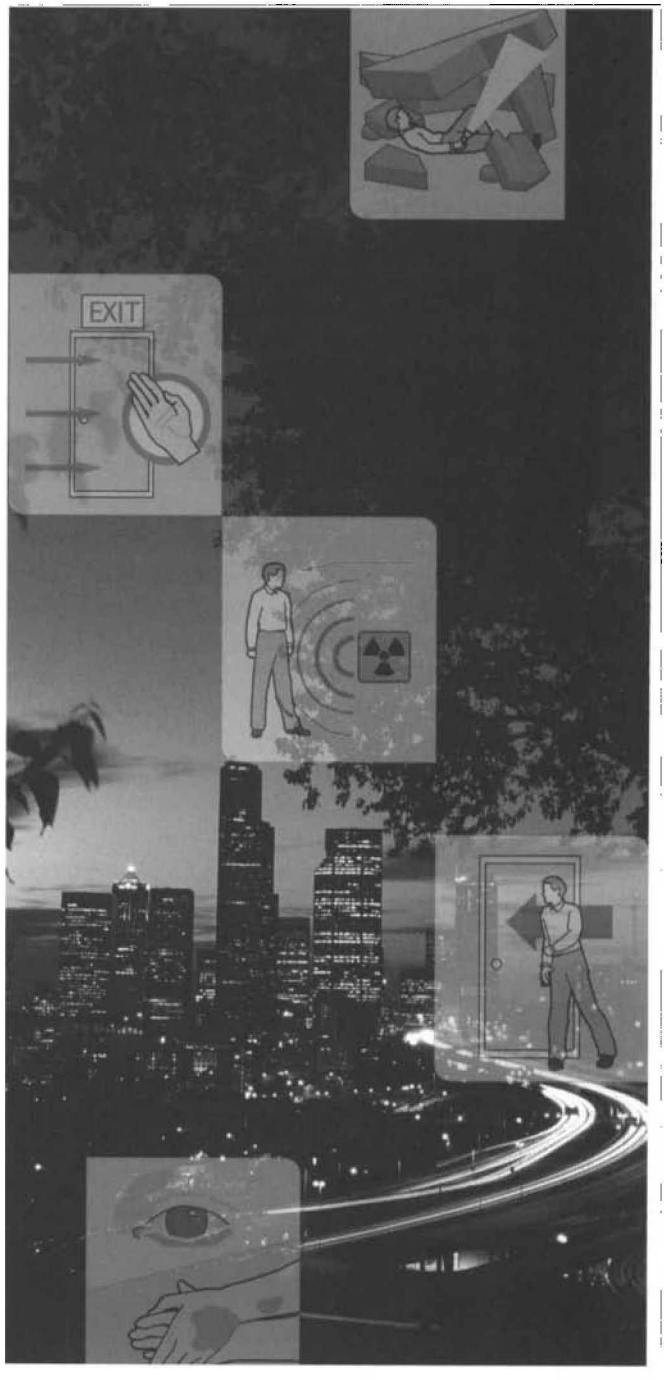
Homeland Security Safety Symbols: Are We Ready?

"TERRORISM FORCES US TO MAKE A CHOICE. WE CAN BE AFRAID. OR WE CAN BE READY."
— Secretary Tom Ridge, U.S. Department of Homeland Security

BY CHRISTOPHER B. MAYHORN, MICHAEL S. WOGALTER, & JENNIFER L. BELL



The September 11, 2001, terrorist attacks on the World Trade Center and the Pentagon had a profound effect on the U.S. public's perceived sense of domestic security and safety. In response to this demonstrated vulnerability to attack, Congress passed the Homeland Security Act of 2002 (Public Law 107-296), which created the U.S. Department of Homeland Security (DHS). Among numerous other strategic objectives, this organization seeks to promote public education and emergency preparedness should further attacks occur.

On February 19, 2002, DHS unveiled a $100 million national public service advertising campaign titled "Preparing Makes Sense. Get Ready Now," which is supported by the Advertising Council. The centerpiece of the campaign is a Web site (*http://www.ready.gov*) designed to inform citizens how to prepare for national emergencies and how to respond to specific scenarios that might occur during a nuclear, chemical, or biological terrorist attack. "Preparing Makes Sense" employs pictorial safety symbols to communicate the nature of the hazards and the behavior necessary to avoid injury. For instance, a number of symbols are associated with radiological protective actions (e.g., reducing exposure and finding shelter) that can be taken following a terrorist attack involving nuclear materials. Although details concerning the origin and methodologies used in the design of the DHS symbols are scarce, one source states that "content came primarily from the Federal Emergency Management Agency, the Red Cross, and military experts" (Jackson, 2003).

In this article, we first describe the general benefits and limitations of pictorial safety symbols. Next, we evaluate one form of the efficacy of the DHS pictorial safety symbols by testing the comprehension of these symbols. Finally, we describe how human factors/ergonomics research methodology might be employed to improve the effectiveness of the symbols and further the goals of DHS. (A related study is described on page 12.)

BENEFITS AND LIMITATIONS OF PICTORIAL SAFETY SYMBOLS

One approach to warning design uses pictorial symbols to supplement or replace text warnings (Dewar, 1999). An everyday example of a pictorial warning is the "no smoking" symbol. When this symbol is encountered at a gas station, most people know that it means not to smoke, light a match, or flick a butane lighter while pumping gas because an open flame or a spark might trigger a fire or an explosion. This mundane symbol helps to avoid hazards in the environment that might lead to injury or death by attracting people's attention (Kalsher, Wogalter, & Racicot, 1996; Sojourner & Wogalter, 1998). The "no smoking" symbol also reminds people to behave safely by cueing their existing knowledge within memory (Leonard, Otani, & Wogalter, 1999).

Another benefit associated with the use of symbols is that people who cannot understand printed text warnings might be able to comprehend pictorial safety information. Safety symbols also make it possible for individuals who are illiterate or not conversant in the language of the safety information text to be warned of hazards in the surrounding environment. Given the increasing cultural diversity of the U.S. population, the use of pictorial safety symbols has the potential to be "culturally neutral" (Edworthy & Adams, 1996).

Ideally, pictorial safety symbols offer a number of benefits that should enhance public safety behavior through effective communication of hazard-related information. However, there are limitations to the use of safety symbols that, in some instances, detract from their effectiveness as warnings. Symbols that bear a resemblance to actual objects or procedures are generally more understandable than symbols that do not (Dewar & Arthur, 1999). For instance, pharmaceutical labels designed to communicate the necessity of taking the medication twice daily in the morning and at night might be more effective if depictions illustrate the action of taking a pill in conjunction with some indication of time of day (e.g., sun or moon).

Even when pictorial symbols are understood, they may be interpreted in a literal, more limited domain. For instance, a person who encounters the "no smoking" symbol may make the literal interpretation that smoking cigarettes is not allowed but fail to realize that *all* sources of flame and sparks are dangerous at places such as the gas station. Abstract concepts that can be visualized only with difficulty, such as radiation and biohazard or even the concept of time, are often difficult to convey pictorially (Hicks, Bell, & Wogalter, 2003; Leonard et al., 1999).

Past research indicates that symbols may not be understood by members of the at-risk population at levels expected by the symbol designers (Schroeder, Hancock, Rogers, & Fisk, 2001; Wolff & Wogalter, 1998). Therefore, it is important that comprehension testing be conducted to determine the effectiveness of proposed symbols *before* they are implemented for use. Published standards have provided guidance for warning designers by quantifying what level of comprehension constitutes an acceptable symbol. An American national standard (ANSI Z535.3; National Electrical Manufacturers Association, 2002) requires that at least 85% of the answers from a sample of 50 or more people should correctly identify the message content being communicated by a pictorial safety symbol. The International Organization for Standardization (ISO 3864-1984) requires a 67% rate of comprehension for safety symbols to be judged acceptable. Furthermore, the sample should generate no more than 5% critical confusions, which are defined as answers that are opposite to the intended concept or wrong answers that could lead to behavior resulting in death or injury (ANSI Z535.3).

Given the importance of the Homeland Security initiative, in the next section we describe a comprehension study we conducted to test the understanding of a sample of the at-risk population for the message content being conveyed by the DHS pictorial safety symbols.

A TEST OF THE HOMELAND SECURITY SAFETY SYMBOLS

We planned a comprehension study of the DHS safety symbols to address the likelihood that the American public would be able to effectively use the symbols to avoid injury or death in the event of a terrorist attack. Given the abstract nature of many of the symbols, we expected the results to demonstrate some degree of confusion for the message content being conveyed by the symbols.

We enlisted 57 people (28 men, 29 women) representing a range of ages and races from the Raleigh-Durham, North Carolina, area to serve as participants. They were age 18–84, with an average of 38.1 years. The sample was 78.9% Caucasian, 15.8% African-American, and 5.3% Hispanic-American. The participants were tested in groups of three to five for their comprehension of a set of 24 of the pictorial symbols (Figure 1) developed by DHS.

There are limitations to the use of pictorial safety symbols that, in some instances, detract from their effectiveness as warnings.

Instructions were given in both oral and written form. Following completion of the consent form and a brief demographic questionnaire, participants answered open-ended questions to test their comprehension of the safety symbols. Open-ended procedures are considered to be more ecologically valid than other types of test methods (e.g., multiple choice) because they mimic the cognitive operations that people might undergo when they encounter safety symbols in the real world. That is, when people encounter a safety symbol, they do not select from a set of alternative answers; instead, they generate meaning from the symbol in much the same fashion as is being tested with the open-ended procedure. Because symbols are supposed to cue existing knowledge in memory, unfamiliar message content is interpreted through the use of contextually based infer-

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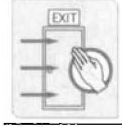
Figure 1. Department of Homeland Security safety symbols and participant feedback data related to comprehension and critical confusion.

Safety Symbol	Message Content	% Correct Comprehension	% Critical Confusion	# Participant Design Suggestions
	Tap on pipe or on wall so that rescuers can hear you.	7.0%	0.0%	34
	Use a whistle if one is available. Shout only as a last resort – shouting can cause a person to inhale dangerous amounts of dust.	12.3%	86.0%	24
	If the door is not hot, brace yourself against the door and slowly open it.	15.8%	64.9%	26
	If you see signs of a chemical attack, try to define the impact area or where the chemical is coming from.	33.3%	21.1%	27
	Avoid unnecessary movement so that you don't kick up dust.	42.1%	15.8%	24
	Use the back of your hand to feel the lower, middle, and upper parts of closed doors.	45.6%	31.6%	27
	In the event of a biological attack, public health officials may not be immediately be able to provide information on what you should do. However, you should watch TV, or check the Internet for official news as it becomes available.	47.4%	35.1%	31
	Many sick or dead birds, fish or small animals are also cause for suspicion.	47.4%	40.4%	26
	If you catch fire do not run.	59.6%	28.1%	15
	Seek emergency medical attention.	63.2%	5.3%	11
	If possible use a flash light to signal your location.	63.2%	7.0%	10
	Time: Minimizing time spent exposed will also reduce your risk.	63.2%	15.8%	24

(Figure 1. continued)

Safety Symbol	Message Content	% Correct Comprehension	% Critical Confusion	# Participant Design Suggestions
	If your eyes are watering, your skin is stinging, you are having trouble breathing or you just think you have been exposed to a chemical, immediately strip and wash. Look for a hose, fountain or any source of water.	71.9%	12.3%	24
	Stop, drop and roll.	78.9%	8.8%	6
	Do not go back into a burning building, and carefully supervise small children.	78.9%	3.5%	23
	Shielding: If you have a thick shield between yourself and radioactive materials, more of the radiation will be absorbed by the thick shield, and you will be exposed to less.	82.5%	10.5%	16
	Get away from the substance as quickly as possible.	42.1%	15.8%	24
	Do not use elevators.	84.2%	3.5%	8
	It would be better to go inside a building and follow your plan to "shelter-in-place."	84.2%	10.5%	9
	Use a wet cloth to cover nose and mouth.	96.5%	0.0%	8
	Wash with soap and water, but do not scrub the chemical into the skin.	98.2%	1.8%	24
	Take shelter against your desk or a sturdy table.	98.2%	0.0%	5
	Exit the building as quickly as possible.	98.2%	1.8%	9
	Do not open the door if it is hot. Look for anther way out.	100.0%	0.0%	2

ence. Furthermore, previous research suggests that test methods such as multiple-choice tests artificially inflate symbol comprehension scores (Wolff & Wogalter, 1998).

Each participant encountered each of the 24 DHS symbols twice in two phases. During Phase 1, participants received a 25-page test booklet that contained one pictorial safety symbol per page. Symbols were approximately 3 × 3 inches (7.3 cm × 7.3 cm) in size. Each page contained a text description to convey the situational context in which such a symbol might be encountered and two open-ended comprehension questions ("Exactly what do you think this symbol means?" and "What action would you take in response to this symbol?").

Our participants believed that 19 of the 24 DHS pictorial safety symbols are unacceptable for communicating hazard-related information.

For example, the first symbol presented in Figure 1, designed to convey "Tap on pipe or on wall so that rescuers can hear you," was accompanied by text that described the situational context as something encountered when "you are trapped in debris following an explosion." The inclusion of context was designed to further heighten the ecological validity of the open-ended procedure because real-world safety symbols usually exist in contexts that provide cues to their meaning, thereby heightening comprehension (Wolff & Wogalter, 1998). Overall, the procedure we used is consistent with the guidelines in the ANSI Z535.3 safety symbol standard (National Electrical Manufacturers Association, 2002). The first page encountered during Phase 1 included a practice symbol ("no smoking") to illustrate the task, but the remaining pages of the test booklet were randomized for each participant.

Following the completion of Phase 1, participants received another 25-page booklet with the same symbols, one per page, in a different random order (except for the first practice symbol). In the Phase 2 booklet, we provided the intended message content of each symbol and asked participants to suggest ways that the design of each pictorial symbol could be improved. They were told to proceed through their booklets with no time restriction in the page order given and not to change earlier answers. All participants were thoroughly debriefed once data collection was completed. The experimental sessions lasted about 45 minutes.

Two independent raters scored the open-ended responses. Interrater reliability, which was determined by dividing the number of judgments when the raters agreed by the total number of judgments, was 90.2%.

COMPREHENSION RESULTS

Figure 1 illustrates the percentage of correct responses per symbol in ascending order. Compared with the ANSI Z535.3 85% correct criterion, our participants believed that 19 of the 24 DHS pictorial safety symbols (or 79%) are unacceptable for communicating hazard-related information. Using the more lenient guidelines of ISO 3864, which require 67% comprehension (and which also uses a slightly different method of scoring, not performed here), 12 of the 24 DHS symbols (or 50%) are unacceptable. The three symbols with the lowest rates of comprehension are intended to illustrate the need to (a) "tap on a pipe or wall" to attract rescuers when trapped in debris (7.0%); (b) "use a whistle if one is available" but not to yell when trapped in debris (12.3%); and (c) determine the source of a chemical attack because "many sick or dead birds, fish or small animals are cause for suspicion" (33.3%).

Figure 1 also includes the percentage of critical confusions (when a participant guessed the opposite of the intended meaning). Compared with the ANSI Z535.3 recommendation that acceptable symbols have no more than 5% critical confusions, 16 of the 24 symbols tested had critical confusion levels above 5%. The three symbols with the highest critical confusions were those meant to illustrate (a) "use a whistle if one is available" but not to yell when trapped in debris (86.0%); (b) "if the door is not hot, brace yourself against the door and slowly open it" (64.9%); and (c) "many sick or dead birds, fish or small animals are cause for suspicion" (40.4%).

Figure 2 lists some of the qualitative comments that illustrate participants' incomplete understanding of these three particular symbols. As these sample responses indicate, participants thought they should yell when trapped under rubble, violently open a door (not mentioning to check whether the door is hot because of fire), and keep animals out of the water when a chemical hazard is detected.

SUGGESTIONS TO IMPROVE SYMBOL COMPREHENSION

Why was symbol comprehension so low and the frequency of critical confusions so high? Perhaps the message content was questionable or counterintuitive. Consider being trapped in debris as illustrated in the "use a whistle if one is available" symbol. If a whistle is available – which is a questionable assumption – would a person trapped under rubble have the freedom of movement to reach into his or her pocket, bring the whistle to the mouth, and blow? Is it feasible *not* to yell for help, especially if injured?

Abstract concepts that hinder visualization are difficult to convey. If a person is trying to exit a building and encounters the symbol "if the door is not hot, brace yourself against the door and slowly open it," a symbol may fail to effectively convey the need to proceed slowly. As there is no indication of heat (e.g., flames or the color red), people may not understand that they need to check the door for heat before they open it. The symbol "many sick or dead birds, fish or small animals are cause for suspicion" is equally abstract because a course of action is not clear. The symbol depicts a person "thinking" but does not convey any sense of urgency or action, such as evacuating the area.

What, if anything, can be done to improve comprehensibility of the symbols? Examination of the 435 feedback suggestions for improving symbol design elicited during

Figure 2: Qualitative examples of critical confusions.

Safety Symbol	Message Content	Examples of Critical Confusions
	**Use a whistle if one is available. Shout only as a last resort – shouting can cause a person to inhale dangerous amounts of dust.**	Yell when you hear a whistle. Blow a whistle or yell to get attention. When you hear a whistle, yell for help.
	**If the door is not hot, brace yourself against the door and slowly open it.**	Use your body to break down the door. OK to use exit. Push or break down door to exit. Door is the way to safety. Use door. Push your way out of doors. Use force to get through blocked doors.
	**Many sick or dead birds, fish or small animals are also cause for suspicion.**	Avoid eating fish or fowl. Drink only bottled water and breathe through a filter. Catch and release the fish. Do not shoot the birds. No animals or fish in water.

Phase 2 provided insight and demonstrated participants' willingness to share their opinions regarding their understanding of the DHS symbols. The total number of suggestions made by each participant for all the DHS symbols ranged from 0 to 20, and the mean number of design suggestions made per participant was 7 ($SD = 5.1$). As indicated in Figure 1 (pages 8–9), multiple suggestions were received for each of the symbols ($M = 18.1$, $SD = 9.3$), but the number of comments per symbol ranged from 2 to 34. We conducted a Pearson product-moment correlation to examine the relationship between symbol comprehension and the number of suggestions. Results of this test revealed that the number of participant design recommendations increased as symbol comprehension decreased, $r\ (24) = -.72$, $p < .001$. This significant negative correlation illustrates the willingness of participants to make comments when they realize that they do not fully understand a safety symbol.

Despite the large number of design suggestions, the quality of those suggestions varied considerably – for example, the symbol meant to illustrate the necessity of not running if you catch fire. As Figure 1 illustrates, 59.6% of the participants correctly comprehended the meaning of this symbol, and in Phase 2 it elicited 15 suggestions for improvement. The qualitative comments were useful in identifying the source of participants' misunderstanding of this symbol, but few specific comments might be used to improve the physical design of the symbol. Of the limited number of design ideas that might be implemented during future iterations to improve this symbol, all focused on clarifying (a) that the person depicted by the symbol was on fire and (b) changing the attributes of the negation (i.e., slash placed over another symbol) symbol to illustrate not running.

Two suggestions that provided sufficient detail for altering the symbol to clarify that the person was on fire included "more fire on the individual and no background fire" and "make the guy look like he is more on fire." Three suggestions that might be implemented to improve the use of the negation symbol included "the slash should be across the person," "make sure that the man is visible above the crossbar," and "diagonal is too covered." Guidelines already exist to improve the legibility of pictorial symbols using the negation symbol (see Murray, Magurno, Glover, & Wogalter, 1998). Therefore, the utility of collecting qualitative design recommendations from participants for the purpose of developing or modifying symbol design was limited to identifying general sources of misunderstanding, but they did not appear useful as design solutions for this group of symbols.

The participants' design recommendations, though insightful and accurate, would be very difficult to execute and may not result in better DHS symbols.

Low comprehension and the high percentage of critical confusions in this study, in conjunction with the number of qualitative design comments from participants, suggest the need for further testing and redesign of these pictorial symbols, or perhaps the elimination of some of the symbols because the concepts to be communicated are not amenable to pictorial communication. In the latter case, simplified text (perhaps tested in Spanish as well as English) would be preferred.

HF/E CAN AID IN SAFETY SYMBOL IMPROVEMENT

It is unclear whether redesign would result in more usable symbols given the complex and abstract nature of the messages these symbols are designed to communicate. To illustrate, Figure 1 indicates that participants made 26 design suggestions for the symbol meant to depict opening a door