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WARNING SYMBOLS

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ABSTRACT

Symbols (also called pictorials, pictograms, and icons) are graphical forms that are used to present information. They are sometimes distinguished from text, and they also accompany and support text. In warnings, safety symbols may be used to increase salience, comprehension, and compliance to warning information. The effectiveness of a symbol depends on several factors, including the concept, the context, depiction quality, prior training, and target group knowledge. The literature suggests that symbols should have relatively simple, bold forms. They should remain legible when reduced in size, seen at a distance, and in degraded environmental conditions. Symbol comprehension tests using open-ended testing (and in relevant context) can provide input into symbol design that benefits understanding in relevant target audiences. Research literature suggests that concrete (representational) symbols and concepts are better than abstract (arbitrary) symbols and abstract (low visualizable) concepts. In developing new symbols, iterative design and testing procedures are recommended. Informal and formal methodologies for evaluating symbols are described.

INTRODUCTION

Symbols are graphical forms that convey information. Symbols are sometimes called pictorials, pictograms, pictographs, pictures, graphics, drawings, visual representations, and icons. In this chapter, the primary term will be symbols, and it will encompass all of the these terms.

Symbols are increasingly being used as a means of conveying safety information in a wide variety of applications (Boersema & Zwaga, 1989; Easterby & Hakiel, 1981). Research on safety symbols is the focus of this chapter.

Purposes of Symbols

An ultimate purpose of symbols in warning is to promote safety-appropriate behavior. Their ability to facilitate compliance behavior depends on the adequacy of several intervening aspects. These may be framed by the questions: (a) Does it call attention to itself? (b) Is it legible? (c) Is it understandable? These aspects and compliance are briefly defined in the following paragraphs. More detailed treatment of each follows.

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FIGURE 12.1. Safety alert symbol.

Does It Call Attention to Itself? Some symbols have characteristics that can alert and switch attention toward themselves. This alerting value is important because many environments are cluttered with varieties of stimuli that could potentially distract attention from a warning. A well-designed symbol with conspicuous (salient) features will have more prominence to stand out from other stimuli in the immediate environment. A common symbol in warnings is the safety alert symbol (a triangle surrounding an exclamation point) as shown in Fig. 12.1. Its main purpose is to switch attention and alert the presence of a warning.

Is It Legible?. The viewer needs to be able to discern the relevant features of the symbol. There are aspects of its rendering that may increase legibility. In general, the forms should be comprised of large, bold, relatively simple components having high foreground-background contrast and devoid of irrelevant detail. Legibility may be affected by conditions such as too much or too little lighting, the presence of smoke or fog, and long-term exposure to environmental elements that could degrade the image.

Is It Understandable?. Symbols are used to represent concepts. Thus, a primary purpose of symbols is comprehension. It refers to a person's understanding of the meaning the symbol, which may or may not be the same as the meaning the symbol was intended to express.

Warnings are generally intended to convey the following three concepts: the hazard, the means of avoiding the hazard,

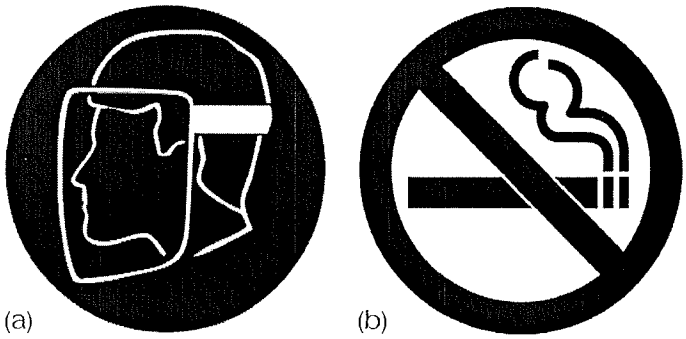


FIGURE 12.2. (a) Proscriptive symbol for face protection; (b) Prohibition symbol for no smoking.

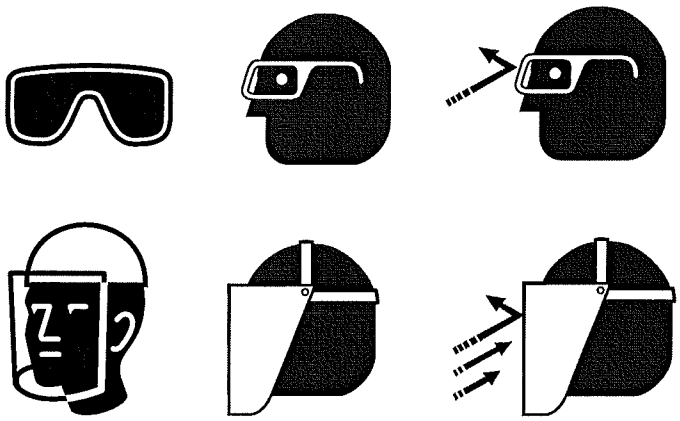


FIGURE 12.3. Symbols for eye and face protection. Note that the two symbols in the third column also show an indication of the reason for wearing the protective equipment.

and the consequences of not avoiding the hazard. Symbols may take the role of representing one or more of these concepts. Few symbols convey all three concepts. However, more than one symbol could be combined or accompanied by text to more fully cover the three.

Symbols are increasingly being used to communicate to individuals or groups who have limited or no reading skill in a particular language and are unable to read a printed text warning. Well-designed symbols serve to facilitate comprehension.

Do People Comply?. Safety symbols can promote safety behavior. Some symbols provide behavioral directions of what to do or not do to avoid harm. Figure 12.2 shows an an example of two symbols with information on directives. One is prescriptive and the other is proscriptive. Prescriptive symbols depict behavior to be performed to avoid a particular hazard as in Fig. 12.2a for "wear face protection." Proscriptive symbols describe prohibited behavior, such as in Fig. 12.2b for "no smoking." However, some symbols do not provide specific guidance on what behavior to perform (or not to perform) or the consequences. Another category, descriptive symbols may only indicate the existence of a hazard (e.g., flying debris), whereas others might incorporate more information into a single symbol as shown in Fig. 12.3. Note that the two symbols in the third column also incorportate information about the hazard. Sometimes behavioral information may be given by another symbol or by a textual instruction statement.

COGNITIVE PROCESSING

As mental processing of stimuli is important for symbol success, this section reviews several relevant concepts derived mostly from research in cognitive psychology. It makes use of research associated with a broader literature concerning graphical stimuli in general rather than restricting it to safety symbols. Thus, some citations concern research involving graphics. Although this review treats symbols in a very general sense, the coverage

provides some insight on the differences between symbol and text processing relevant to safety symbols.

The old adage "a picture is worth a thousand words" is sometimes a valid description. Pictures can convey a lot of information, and sometimes they can do it in a smaller space and with less effortful processing than would be needed to convey the same information in a textual form (Dreyfuss, 1970). There are several reasons. Wordings can sometimes be complex and require decoding and transformation to be understood. Some symbols are able to directly represent the concept and can be processed relatively easily. Thus, text processing can be more difficult than that of some highly representative pictures.

No language in the world has the vocabulary to describe all of the nuances and details of most pictures. Describing the specific details of pictures using conventional terms in common language could require rather lengthy texts. Although no one would need to describe all of the details of a symbol—just its meaning—the point is that pictures and words may be processed somewhat differently. A well-designed representational symbol may in a very short glance activate associated memory structure relatively quickly. Unfortunately, not all symbols perform so well or are not so readily comprehended. Sometimes a picture is not worth a thousand words. Why? What are the reasons and issues involved? Theory provides some perspectives.

Theory

There is cognitive theory related to symbol processing. Paivio (1990) described a dual code theory as a cognitive system with two independent codes. One code involves verbal (language) processing and the other involves visual-spatial (imaginal) processing. Speech and printed text are processed by the verbal system, and graphics, including pictures, are processed by the visual-spatial system. When a picture is accompanied by text the two codes can work independently of each other, but they can also interact. Similarly, Kosslyn, Ball, and Reiser (1978) suggested that there is a separate visual- spatial system that operates analogically and spatially and is different than that used in analytical and language processing. Other researchers do not distinguish between two systems. For example, Pylyshyn (1973) argued that pictures and textual material are processed using the same underlying mental components (i.e., one system—not two). All of these notions have empirical support in the cognitive psychology literature. The differences in viewpoint are probably due to different levels of analysis. On the one hand, processing involving pictures and words probably overlaps to some extent which supports Pylyshyn's viewpoint. On the other hand, there is a large body of research supporting Paivio's and Kosslyn's a distinction between two systems. The body of evidence suggests that symbol processing may be at least somewhat different than text processing.

Processing Speed

Some researchers have compared the processing speeds of text and symbols. Processing speed is important in certain real-world situations. Sometimes there is very limited time to respond to a warning, such as with some roadway signs. Faster processing speeds indicate the relative ease with which stimuli can be processed.

Ganier (2001) found results indicating that mental representations can be constructed faster with pictures than with text. Rosch (1975) demonstrated that categorizing pictures was significantly faster than categorizing text. Some symbols have physical shapes corresponding to their underlying concepts, which would facilitate the processes involved in classifying them (Bruner & Olson, 1973; Evans, Hoeft, Jentsch, & Bowers, 2002; Guenther & Klatzky, 1977). Research suggests that some graphics are processed faster than others. A recurring theme is that the closer the match between symbol and the represented concept, the faster the processing because less translation is needed (Green & Pew, 1978; Walker, Nicolay, & Stearns, 1965). Some graphics are more abstract—they less directly represent or depict the concept. Consequently, they require more processing to derive meaning (unless they have been well learned). Given that symbols differ considerably on many characteristics, it is not surprising that some studies find slower processing time, poorer recognition, and greater learning difficulties with pictures and symbols compared to text material (e.g., Lotto, Job, & Rumiati, 1999).

ALERTING VALUE

One of the purposes of symbols is to alert, to call attention to themselves. They may also faciltate attention to associated text (if any). Several studies have shown that warnings with symbols are more noticeable than without symbols. Laughery, Young, Vaubel, and Brelsford (1993) and Bzostek and Wogalter (1999) found a warning with a symbol is detected faster than a warning without one. Similarly, Heck (1996) reported that reaction times to symbols were shorter when the corresponding textual material conveyed the same information (cf. Childers & Houston, 1984). Morrow, Hier, Menard, and Leirer (1998) showed that symbols reduced the time to learn medication information. Kalsher, Wogalter, and Racicot (1996) demonstrated that warnings with symbols are rated as more noticeable than warnings without symbols.

Symbols may be more salient than text because of visual differentiations of shape, size, and color. Usually symbols have unique details and possess more differences in appearance than do the letters of the alphabet. Letters are highly familiar and are more similar to one another than most graphicals symbols

PROTOTYPE DEVELOPMENT

Sometimes there is no usable symbol for a needed safety concept and one needs to be developed. In this section we describe a preliminary phase of symbol development in such cases. Deppa, chap. 37, this volume, describes the methods of symbol evaluation described by the ANSI, 2002, Z535.3 standard: *Criteria for Safety Symbols*. Also, see Goldsworthy and Kaplan, chap. 59,

this volume, for a case study describing the development and evaluation of a teratogen symbol.

Several steps can be taken to produce symbols. The first step is to determine what concept(s) needs to be conveyed. Input from outside sources such as domain/area experts may be needed to determine what the hazard is and other relevant information.

The second step is to determine whether there already exists available symbol(s) for the concept or at least something that is similar to what might eventually be used. This process could involve examining existing similar products to see if they are using a symbol for the concept. Other sources of symbols include collections of prepared symbols (e.g., Dreyfuss, 1972; Olgyay, 1995), commercial safety catalogs (e.g., Lab Safety Supply, Brady, Seton), public domain clip art, existing standards (e.g., ANSI, 2002; ISO, 2001) and guidelines (FMC Corporation, 1985; Westinghouse Electric Corporation, 1981), and searching the Internet. For more information on existing symbols, see in particular, Peckham, chapters 33 and 35, this volume, on American National Standards Institute (ANSI) and International Organization for Standardization (ISO) standards. See also the list of standards in this Handbook's Appendix: Bibliography of Standards (Miller & Person, this volume).

Sometimes an existing symbol does not exactly convey the desired concept. Existing symbols should be considered at the early stages of symbol development because they can serve to suggest alternative designs (Green, 1979), and sometimes only minor modifications using computer software can make the symbol satisfactory for its desired purpose.

Models of good symbol forms can be found in the annexes of the ANSI (2002) Z535.3 standard. ANSI (2002) Z535.3 also provides some suggested guidelines on development. Another important and useful source for symbol development is the research literature addressing important considerations for successful symbol development (e.g., Zwaga, Boersema, & Hoonhout, 1999).

If no existing useful symbol can be found, then the next critical symbol development stage is the production of prototype symbols (see also Goldsworthy & Kaplan, chap. 59, this volume). Researchers may have some initial ideas about what the symbol should look like. But an important part of the process is to get input from the target audience. For example, several small groups of people could be asked to participate for the purpose of generating and enlarging the set of potential ideas for symbols. These groups may involve a few domain experts and a few representative at-risk persons who are asked to draw some rough images that would convey the hazard, consequences, and instructions. The sample of at-risk persons should be given:

- An elaborative description concerning the hazard, the potential consequences, and what a person can do to avoid the consequences.
- Information about the contexts in which the symbol might be seen in application.
- Other relevant background information.

The rough drawings produced by participants can then be redrawn by a graphics artist based on designs similar to the example visual forms in the annex of ANSI (2002) Z535.3 and other guidelines (FMC, 1985; Westinghouse, 1981). The best resulting cleaned up versions would then given to another group of individuals for their opinions and comments. Their input is used to revise the set of symbols. This process of redesign and qualitative assessment (i.e., informal opinions) is repeated with additional small groups of participants until a satisfactory set of prototype images is determined.

If there are several prototypes (preliminary versions) of symbols representing a concept, then a rating procedure may be used to cull down the set (Brugger, 1999; Zwaga, 1989). One procedure involves asking a sample of participants to estimate the percentage of people who would understand each of the symbols (0% to 100%). The set with the highest mean percentage estimates could later be evaluated for actual comprehension.

LEGIBILITY

Relevant parts of symbols need to be distinguishable, that is, important features of the visual image must be seen as separate. Factors that affect legibility include size, viewing distance, contrast (figure ground brightness and color), quality, detail, environmental conditions (dim lighting, smoke, fog), printing and degradation, and the observer's eyesight.

Methodology

Several different methods are used to measure legibility. The best methods replicate the conditions in which the symbol may be seen in the real world. Most experiments approximate this with techniques that present symbols at very short exposure durations or at reduced sizes. Short exposures sometimes occur with signage viewed while riding in vehicles. Size reduction simulates symbols on small product labels and symbols seen at a distance. Legibility tests may involve simulations of degraded environmental conditions such as smoke or fog or of long-term exposure to the elements, such as physical degradation that is due to fading and abrasion. The degraded conditions may also simulate various kinds of sensory impairments (e.g., reduction of acuity and contrast sensitivity that is due to aging). The testing is relatively simple. On being shown the stimulus symbol, participants attempt to identify what was presented. The identifications are scored for accuracy to produce mean proportion correct scores, which are used to compare conditions differing on some legibility dimension. Researchers have used some very clever techniques in the laboratory to measure the effects of degradation. These include the use of simulated smoke (visual noise) on computer screens (Bierman, Raffucci, Boyce, & DeCusatis, 1996; Collins, Dahir, & Madrzykowski, 1992), and creating various degrees of optical blurring (defocusing) to simulate various acuity conditions (Kline & Fuchs, 1993; Schieber, 1994). See also Glasscock & Dorris, chap. 39, this volume.

Larger and Bolder

Generally, larger symbols are more legible than smaller symbols (Frantz, Rhoades, & Lehto, 1999). Thick, bold elements are generally more legible than thin, small details. Legible graphics can become illegible when reduced in size or viewed at a distance. With increasing degradation some details can become illegible before other parts begin to do so. Reducing the space separating the components can render a symbol illegible. The symbol should have high contrast with its background: preferably dark on light or vice versa. As light-dark contrast diminishes the difference between the figure and ground becomes zero, and the object and background cannot be distinguished. Black and white generally produce the highest contrast, but very high contrast can also be produced from certain other color combinations (e.g., saturated red with yellow). See Sanders and McCormick (1993) for more on color contrast considerations in visual displays.

Symbols classified as ISO symbols usually have a surround shape and color to codify the level and type of hazard involved. ANSI Z535.3 symbols sometimes use color (e.g., the prohibition symbol is usually red), but colors of symbols are generally not used to code hazard severity. Also, ANSI Z535.3 does not advocate the use of surround shapes because some research indicates that people do not readily interpret differences in meaning between most basic geometric shapes with the possible exception of triangle and octagon (e.g., Jaynes & Boles, 1990). The other problem is that some shapes such as the triangle and circle can limit the size of the inset symbol, because of the space needed for the shape's border and proper scaling of the symbol inside. Figure 12.4 shows two symbols, one in a triangle and one using about the same space without a triangle. In general, comparable ANSI symbols are larger and more legible than ISO symbols given the same space allocation because the latter usually includes a surround shape.

Depiction Quality

The quality of the artwork can matter. Symbol quality can depend on the perspective and the forms used to represent the concept and what emphasis is given to them. It can depend on the aesthetic expertise of the artist. Guidance on form and perspective are available in design standards (ANSI, 2002; ISO, 2001), guidelines (FMC, 1985; Westinghouse, 1981), and in research (Sanders & McCormick, 1993). Many of the basic design guidelines derive from the gestalt perceptual principles (see e.g., Coren & Ward, 1989). These characteristics include figure-ground, simplicity, contiguity, boldness, and similarity, among others. Symbols that are simple in form and have good foreground-background contrast are preferred. See Dewar (1999; chap. 13, this volume) for more information on this topic.

FIGURE 12.4. Symbols with and without a surround shape using approximately the same amount of space.

Complexity

In general, symbols comprising simple forms are preferred (Mullet & Sano, 1995). Symbols should be elegant, yet simple, in their design (Goonetilleke, Shih, On, & Fritsch, 2001). Bold simple symbols tend to be more legible compared to finely detailed symbols. Irrelevant detail can potentially distract viewers from relevant parts of the symbol. Although simplicity is desirable, it may not always be possible when developing an understandable symbol. Sometimes certain critical details are necessary to convey the concept adequately and to distinguish and particularize the meaning to the viewer relative to other similar, but incorrect, concepts.

Printing

Legibility can be adversely affected by poor production at the printing stage where wet paint or ink may spread or bleed and sometimes fill in important details that would otherwise help to distinguish the characters. A similar problem occurs for some kinds of projected displays (e.g., on computer screens). When light-colored features are displayed on dark backgrounds (light on dark) the stroke width comprising the details may need to be somewhat thinner for legibility than they need to be with dark letters on a light background. The reason is a phenomenon called irradiation in which light spreads out making the stroke widths look wider, reducing the legibility of smaller features (Sanders & McCormick, 1993).

Environmental Conditions

Environment conditions such as the presence of smoke or fog, a massive rain storm, too little or too much light, and so forth may obscure or mask the symbol with varying translucence that could limit the feature's discernability. Furthermore, over time, exposure to sunlight, air pollution, dirt, grime, water, cold, and heat could cause degradation of materials. Color and brightness contrast is reduced making the symbol less noticeable and legible than when it was printed. More information on durability is given by Glasscock and Dorris (chap. 39, this volume).

Prohibition

A commonly used graphic shape is the circle-slash prohibition or negation symbol. This symbol is usually configured as a circle with a single diagonal slash going from the top left quadrant to

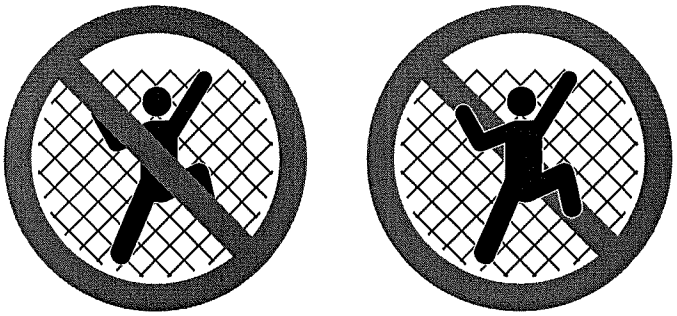


FIGURE 12.5. An example of an over and under slash. (See Color Plate I).

the bottom right quadrant. The slash is usually placed so that it overlays another, internalized symbol (but occasionally it is placed behind the symbol. An "X" over the symbol is sometimes used to denote prohibition instead of the circle-slash. It is important that the slash does not obscure the critical elements of the symbol, which are necessary for the symbol's proper interpretation. For example, Dewar (1976) and Murray, Magurno, Glover, and Wogalter (1998) found that the slash could sometimes obscure critical features of symbols, decreasing recognition of their meaning. Murray et al. showed that simple adjustments such as reversing the symbol could aid identification performance (see also Wogalter, Murray, Glover &, Shaver, 2002). Figure 12.5 shows an example of an over and under slash. The latter does not obscure the inset symbol.

COMPREHENSION

One of the most important purposes of symbols is comprehension (Dewar, 1999). In this section issues and research associated with comprehension are reviewed.

Interpretation

Interpretation is the process of understanding the underlying meaning of the symbol (Goonetilleke et al., 2001). The intended meaning and the meaning that the end-user derives could be different. Another way of saying this is users' interpretation can be incorrect.

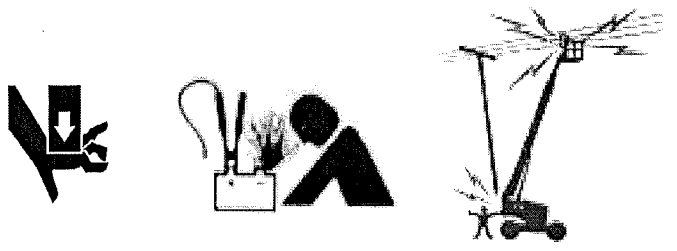


FIGURE 12.6. Three symbols showing both the hazard and consequences.

For any given concept, many possible drawings can be developed. Different aspects of the concept(s) could be emphasized. For example, the symbol might visually convey the nature of the hazard, the hazard-avoidance instruction, the consequences of not avoiding the hazard, or some combination of these. Some examples of symbols that show the hazard and consequences are shown in Fig. 12.6. In addition, the objects in the symbols can be variously depicted by giving different perspectives, different amounts of detail and emphasis, and so forth. Sometimes a minor change to a single component of a symbol can dramatically change its meaning. Several authors describe some of the issues involved in creating and refining symbols (e.g., Dewar, 1999; Magurno, Kohake, Wogalter, & Wolff, 1994; Wolff & Wogalter, 1993, 1998).

A symbol that evokes different interpretations across observers is ambigous. For example, a sign with a symbol of a boot might indicate a shoe store, a shoe repair business, a country and western dance hall, or to indicate that steel-toed footwear needs to be worn in the area (see Leonard, Otani, & Wogalter, 1999). Interpretation is affected by various factors such as context, a topic discussed later.

Critical Confusions

Symbols may be understood fully and correctly, or they may be only partially understood or not at all. Some poorly designed symbols might even give rise to interpretations that are severe distortions. Critical confusions are misinterpretations opposite of the intended meaning. Also, they may be misinterpretations suggestive of unsafe behavior that may lead to injury rather than the avoidance of injury. Three examples serve to illustrate critical confusions. First, consider a symbol on a door to a secure facility, where the symbol is intended to mean "Do Not Enter." A common symbol for this concept is the left-most symbol shown in Fig. 12.7. If, however, it were interpreted to mean entrance, then this error would be a critical confusion. Two other symbols are shown in Fig. 12.7 to mean something similar to the "Do Not Enter" concept, but they could also mean "No Entrance" and "Halt" and a number of other possible meanings.

A second example of a critical confusion is a symbol whose intended meaning is that women should not take the medication while pregnant and should take precautions to avoid getting pregnant while taking it. It is a side-view a pregnant woman with a circle-slash prohibition symbol. However, this symbol has reportedly produced critical confusions by being interpreted by some as a birth control (pregnancy prevention) pill. See Goldsworthy and Kaplan (chap. 59, this volume) on the development and evaluation of alternative birth defects symbols.

A third example of a critical confusion error also relates to the prohibition symbol. Red pigment is commonly used for the circle-slash prohibition symbol, but red inks tend to fade faster than other inks. If the red of the circle-slash on a sign disappears faster than the black ink comprising the associated inset symbol, then later in the life of the sign (if not maintained) the internal black symbol is displayed while the "red" prohibitive portion is not. The result could be the sign conveying the exact opposite of

FIGURE 12.7. Three symbols for "do not enter." The first symbol is more arbitrary (abstract) than the other two. (See Color Plate 2).

that intended. Figure 12.8 shows an example of a sign in which the red prohibition symbol is fading away. See also Glasscock and Dorris (chap. 39, this volume) and Leonard et al. (1999).

Clearly the potential for critical confusions could be disaster. Avoiding them is absolutely necessary for safety symbols. In fact, limiting critical confusions is more important than high comprehension scores.

Literal Interpretation

Consider the symbol shown in Fig. 12.9 for "No Open Flames" as one showing a lit match overlaid with a prohibition circle-slash symbol. Its literal meaning is that no matches should be lit in the area. However, this same symbol is commonly used to represent a concept much broader than that literal meaning—that *all* ignition sources (including spark-generating devices) should be extinguished, usually because of the possible presence of flammable vapors. Potential ignition sources could include motors and electrically powered equipment that produce sparks or pilot lights for gas-powered devices. Use of a symbol depicting a lit match to cover all ignition sources assumes that observers will extrapolate to the broader concept. The problem is that people may make only the literal interpretation and not the broader one. Not everyone will generalize to something broader without additional information or specific training. In other words, a lot is being left for people's imagination. In less than ideal conditions (time constraints, stress, etc.), deeper inferences are less likely. Literal interpretations are more likely. The chapter by Williamson (chap. 56, this volume) shows a more specific and elaborate symbol for a pilot light hazard.

FIGURE 12.8. A symbol with a fading prohibition symbol. (See Color Plate 3).

Comprehension Testing and Criteria

Standards. ANSI, in its Z535.3 standard, has comprehension criteria for symbols, and its annex (appendix) has suggested methodologies for testing symbol comprehension. The Z535.3 standard says that a symbol is considered "acceptable" to be used without a word message panel if it is comprehended by 85% of a sample of 50 participants, and with no more than 5% critical confusion errors.

The best method of evaluating symbol comprehension is to use an open-ended test procedure. The testing procedure is relatively easy to conduct. The symbol is shown and participants respond with their interpretation of its meaning. The open-ended responses are then scored as dichotomous data (either correct or incorrect). The scoring involves two judges in order to assess reliability. The scoring procedure is more difficult than

FIGURE 12.9. Symbol with literal meaning of not lighting a match.

so-called "objective" methods such as multiple-choice tests that can be machine scored. In open-ended tests the correctness of the answers given by participants needs to be interpreted and judgments are made in assigning the scores—making it a more complicated procedure.

Even if these criteria of acceptability are not met, a symbol may still be useful in application. According to ANSI Z535.3, a symbol that does not meet the 85% criterion cannot be used without a word message. In such cases, a symbol could still improve a warning by attracting attention to other symbols or text and reinforcing the text message. Depending on the seriousness of critical confusion errors, symbols might be rejected even though the less-than-5% criterion is met.

ISO's (2001) safety symbol testing procedures are similar to ANSI's, but there are some differences. One is in scoring the participants' answers. ISO counts partially correct answers as a fraction in the total correct, whereas ANSI does not. See Deppa, chap. 37; Peckham, chap. 33, 35; Goldsworthy & Kaplan, chap. 54; this volume, for description of the similarities and differences between ANSI and ISO in more detail.

Comprehension Testing Methods. In general, symbol comprehension has been mainly measured by open-ended tests, multiple-choice tests, and ratings. These methods have been compared in research.

Leonard (1994) contrasted open-ended and multiple choice tests for 15 different symbols. Using a multiple choice test with 4 alternative answers, for each question, Leonard found that 8 of the 15 items produced comprehension of 85% or better and none fell below 50% comprehension, but when using an open-ended test, only 3 of the items approached the ANSI's 85% criterion.

In another comparison, Wolff and Wogalter (1998) gave participants 33 symbols on an opened-ended test or one of two multiple-choice tests. The two multiple-choice tests differed in whether the three incorrect alternatives were plausible or were less plausible (as determined in preliminary testing). The multiple-choice test with less plausible distracter items produced about 30% more correct responses than the other two methods, which did not differ. This result points out that the use of poor alternatives in the multiple-choice test may result in comprehension being overestimated. Another issue with multiple-choice tests is that in real life, people do not have a set of alternatives to choose from, but rather tend to perform a task more akin to open-ended testing.

Frequently, people provide very brief answers in written open-ended comprehension tests (e.g., Dewar, 1999; Wolff & Wogalter, 1993, 1998). However, it is not unusual for judges to score a short, highly general response as incorrect, even though the participant may actually have understood more than they included in his or her answer. This is an important issue in symbol development and testing because of the considerable time and expense involved. It can make it difficult to determine acceptable symbols. If a symbol just misses the ANSI acceptability criterion of 85% (or in other words, 8 or more incorrect answers from the 50 participants), it might be assumed that further research and development (and expense) is needed. The issue is whether a simple, open-ended comprehension test provides an accurate evaluation of what people understand from a symbol. To address this point, Brantley and Wogalter (1999) used a cognitive interview technique combined with open-ended testing to assess understanding of a set of symbols. The cognitive interview involves eliciting further responding, simply asking or prompting people to give more detailed answers. Prompts are given without unfairly suggesting a particular answer and avoiding bias. The results of Brantley and Wogalter showed that the conventional method of open-ended written responses tends to underestimate participants' understanding and that with simple prompting higher comprehension scores were attained. Some of the symbols failed the ANSI Z535.3 comprehension criterion without prompting, but passed with the cognitive interview approach.

Population Estimation. Although formal comprehension tests are almost always advocated and preferred, a less expensive approach, the population estimation technique, has been suggested to reduce the workload and the number of participants required when several prototype symbols are available. The desire is to determine the more promising symbols for a formal comprehension test and cull out the less promising. Indeed, the ANSI Z535.3 (2002) annex provides a similar approach (see Deppa, chap. 37, this volume). The population estimation procedure derives from the work of Zwaga (1989) and Brugger (1999). They had participants estimate the percentage of the population (0% to 100%) that they would expect to understand the meaning of the symbol. For comparison, there was also open-ended comprehension data available that were collected from a different group of participants. Both Zwaga and Brugger found high correlations of the population estimations with open-ended comprehension scores. Because of the high correlation with comprehension scores, the estimation procedure has been proposed as a way to determine comprehension at a lower cost. However, its use as a substitute should be restricted to when the estimations produced are extremely high. Actual comprehension using open-ended tests is still the gold standard. Zwaga and Brugger caution that the estimates themselves can give inflated numbers, so when in doubt, test the symbols for actual comprehension (see also Young & Wogalter, 2001).

Symbol-to-Concept Relationship

Symbols differ with respect to their relationship to the concepts intended to be evoked. Some symbols directly show the concept. Other concepts cannot be so directly depicted. For example, a directly representational symbol for cancer and radio waves would be difficult or impossible to depict because of the inherent physical characteristics of these hazards. Example symbols intended to convey these concepts are shown in Fig. 12.10.

Three categories of representativeness are described in the literature (Dreyfuss, 1972; Lodding, 1983; Modley, 1966):

1. Representational symbols have images that directly or closely relate to the concept.

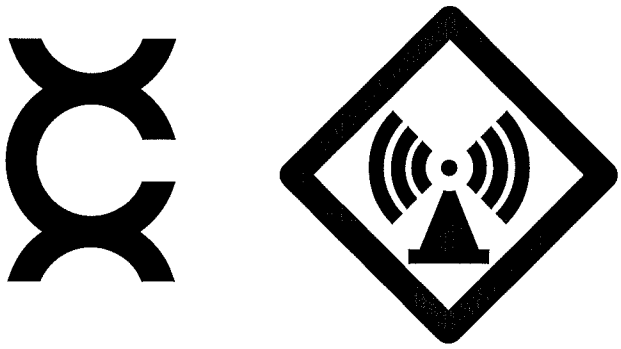


FIGURE 12.10. Two symbols for less visualizable concepts. The first is for cancer and the second is for radio waves.

2. Abstract symbols are images that have a distant relationship to the concept.
3. Arbitrary symbols are images have little meaning in and of themselves or relationship to the concept.

Representational symbols refer to the concept fairly directly and generally depict a familar, easily recognized form (Moyes, 1997). Another name for representational is concrete (Rogers, 1986). An example is the symbol representing "no bicycles" comprisal of a drawing of a bicycle inside a circle-slash prohibition symbol. Another example is a symbol showing fingers being crushed in gears. Generally representational symbols are better comprehended than abstract or arbitrary symbols.

Abstract symbols have some similarity to the concept. The relationship is less direct than found in representational symbols. Generally they need to be learned and the process tends to be more effortful than for representational symbols. The reason is that their interpretation needs to go beyond what is given (Frutiger, 1989). Correct interpretation of abstract symbols depends on context and the individual's background knowledge (Edworthy & Adams, 1996). The lit match prohibition symbol discussed earlier would be an abstract representation of the concept of no sparks or open flames, although it is a representational depiction of the specfic meaning of no lit matches. The cancer and radio waves in Fig. 12.10 are abstract symbols. The cancer symbol relates to the concept in two ways—to the "c" for the first letter of the word and as an abstract form of a broken DNA double helix. The radio waves symbol shows an abstract tower and visible waves. Learning the meaning is easier when people already have some knowldege about the concepts and the hazard.

Arbitrary symbols are images that have no inherent meaning or any representational relation to the designated concept. The connection to its meaning must be learned. The learning process will be more difficult than for representational symbols and many abstract symbols. One example is the "do not enter" symbol mentioned earlier. The conventional depiction showing a circle with a horizontal line does not provide much from which the user can logically deduce the meaning except for an analogy that the horizontal bar could represent a barrier or gate or a blocked doorway. The biohazard symbol and the symbol of confined space (a dead bird) shown in Fig. 12.11 are arbitrary symbols.

Abstract and arbitrary symbols can cue hazards if they are learned. The learning might come from training comprised of simply being told the meaning one or two times. But the problem is the necessity of getting this training, as not all those at risk will receive it. If they do not, they may understand the abstract symbol's meaning. For this reason, comprehensible representational symbols that need little or no training are preferred whenever possible.

Although we have described three categories of symbols (representational, abstract, and arbitrary), most symbol researchers conceive the symbol-to-concept dimension consisting of a continuous scale from not representative to extremely representative or sometimes a continuum from very concrete to very abstract (e.g., Leonard et al., 1999; Young & Wogalter, 2001). In this scheme, arbitrary symbols are considered the most extreme version of abstract symbols.

Most symbol comprehension studies show that concrete, specific symbols are comprehended better than abstract, general symbols (e.g., Davies, Haines, Norris, & Wilson, 1997; Nakata, Campbell, & Richman, 2002; Silver & Perlotto, 1997). Concrete symbols generally contain more detail and are visually more complex than abstract symbols (Garcia, Badre, & Stasko, 1994; Rogers, 1986; Stammers, George, & Carey, 1989). It is interesting to note that, the notion that concrete symbols are more detailed appears to conflict with the guideline that symbols should be relatively simple in form (Easterby, 1970; Rogers, 1986). Byrne (1993) found that simplicity was relevant especially when response time to a symbol is important. Nevertheless, simplicity is not always possible when at least some relevant detail is needed to distinguish the symbol from similar looking one(s) with different meanings. Irrelevant detail is to be avoided as it may distract viewers from relevant components, may make it less legible under degraded conditions, and may increase the viewing time needed.

Some of the conflicts in the results regarding detail and concreteness may depend on the sets of symbols used in the particular studies. McDougall, Curry, and deBruijn (1999) suggested that concreteness and complexity are different dimensions, and that concreteness is more important than complexity with respect to comprehension (McDougall & Curry, 2000). Although we have described some distinctions among symbols in terms of concreteness and abstractness, their notions are somewhat muddled in the literature. Their use is somewhat casual, with some confusion regarding whether it is the symbol or the concept that is abstract or concrete. The concept the symbol is intended to represent may be concrete or abstract or somewhere

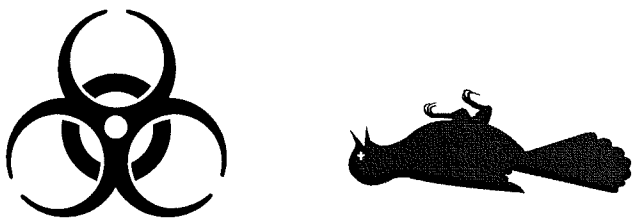
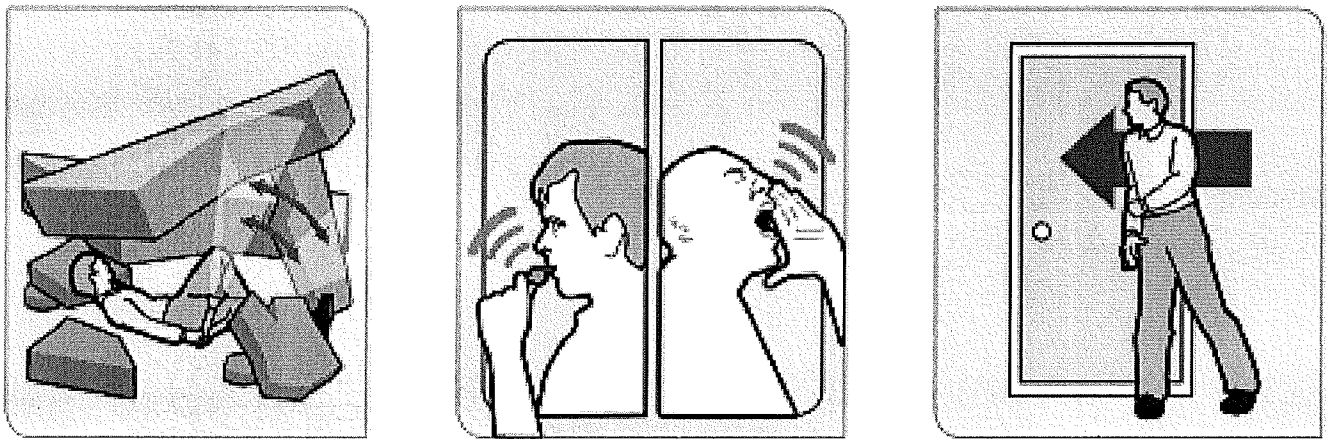


FIGURE 12.11. Two abstract symbols. One is for biohazard and the other is for confined spaces.



(a) (b) (c)

FIGURE 12.12. Three symbols from the U.S. Department of Homeland Security. They are intended to mean: (a) Tap on pipe or on wall so that rescuers can hear you; (b) Use a whistle if one is available. Shout only as a last resort—shouting can cause a person to inhale dangerous amounts of dust; (c) If the door is not hot, brace yourself against the door and slowly open it.

between the two. But the way the symbol is rendered may also be abstract or concrete. A symbol depicting a ladder placed at a particular angle to a wall would be a concrete depiction. A symbol showing a more general impressionistic view of the ladder setup (perhaps just showing two thick lines, one vertical and one at an angle) would be more abstract. Thus, a concrete concept can be presented as an abstract symbol. This situation is different than the concept itself being abstract. Although biohazard is a real concept, it can be considered abstract because it is used for broad classes of agents, some of which are not readily visible. The interlocking partial circles of the biohazard symbol is an abstract symbol of an abstract concept. But an abstract concept can sometimes be drawn more concretely. A more concrete symbol for biohazard might be like the biological waste symbol tested by Leonard (1994), which used a picture of a broken hypodermic needle. Although this symbol did not reach the level of comprehension required by the ANSI Z535.3 standard, it outperformed the conventional abstract one. Abstract concepts are usually drawn as abstract symbols. The reason is that abstract concepts often do not have a readily imageable, visualizable associate (Dewar, 1999).

Hicks, Bell, and Wogalter (2003) examined the concreteness and abstractness issue somewhat differently. They reasoned that the concepts themselves play a substantial part in symbol comprehension. If the concept is abstract, not highly visualizable, and/or would require a complex depiction, then a symbol for that concept is likely to be poorly comprehended. Hicks et al. (2003) had participants rate a set of *worded concepts* (not the actual symbols) that were the referent meanings of 50 actual symbols. The ratings were made on the dimensions of: abstractness/concreteness, visualizability, and simplicity of image needed. They found that all three ratings were highly interrelated. The important part of the study is that they used these ratings to predict actual comprehension performance for actual symbols currently in use for these concepts. Comprehension scores for these symbols were taken from another study by Young and Wogalter (2001) who had 50 participants give open-ended responses for 50 symbols, which were scored by three independent judges. Hicks et al. (2003) found a moderate-to-high prediction of the comprehension scores based simply on ratings of the textual concepts. Visualizability (i.e., how easy is it to visualize an image depicting the concept) produced the highest correlation, but the other two dimensions were also highly correlated with comprehension. Other examples of complex concepts not easily depictable are shown in Fig. 12.12. These are from the U.S. Department of Homeland Security. The results of Mayhorn, Wogalter, and Bell (2004) showed that these and other symbols were very poorly comprehended.

The Hicks et al. (2003) result has important implications for symbol development. Given the relatively high costs involved in developing and evaluating new symbols, there is a benefit in predicting the cost (amount of time, effort, expense) and likely success of an eventually developed symbol. For example, if the concept is easy to visualize and is very concrete, then a symbol for the concept should be relatively easy to develop (low cost). But if a concept is difficult to visualize and relatively abstract, then the project would likely be more difficult (take longer, cost more, and require many iterations of design and testing). Even with that effort, the resulting symbol might still have a difficulty passing the Z535.3 criteria. The costs and limitations of training need to be considered. Of course, the prediction model is not intended to discourage symbol development, but to increase awareness of the difficulties with regard to abstract, nonvisualizable concepts. Certainly when the hazard is important and with serious consequences, then it is wise to try to use a good symbol even if it is difficult to produce.

FIGURE 12.13. Slippery floor symbol with a squiggley line.

Small details in symbols can have large effects on comprehension (Dewar, 1999; Sjoqvist, 2000). Irrelevant details in pictures could distract attention from relevant details. For example, Collins, Lerner, and Pierman (1982) reported that some participants interpreted a squiggle line on the lower portion of a slippery floor symbol as a snake (rather than an artist's depiction of slippery). As similar symbol is shown in Fig. 12.13.

Critical components of symbols could be highlighted to distinguish them from less important details. One example is the radiant heat (i.e., wavy lines) from a hot surface displayed in Fig. 12.14, which is frequently printed in the color red.

Combination With Text

Various combinations of text and symbols may be used in presenting warning information. Research has evaluated the relative contributions of text and symbols. Young and Wogalter (1990) found that both highlighted text and the presence of symbols in owner's manuals for a gas-powered electric generator and a natural gas oven improved memory and comprehension of the warnings in the manuals. Sojourner and Wogalter (1997) found warnings in pharmaceutical package inserts to be more effective, understandable, and recallable when presented with both symbols and text than in either format alone. In a later study, Sojourner and Wogalter (1998) used memory and comprehension as performance measures and obtained a similar pattern of results. Ehlers (1999) tested five pictograms with individuals who used the antibiotic amoxicillin. One group received the usual verbal labeling, whereas the other group received verbal labeling and pictograms. A pharmacist also counseled all participants. Forty percent of the group with the pictograms complied with the label's procedure, whereas none with the text-only labeling complied.

Together these results suggest that textual warnings can be enhanced with the presence of symbols. One caution is with the use of incomplete symbol sets (Sojourner & Wogalter, 1997). Using symbols to accompany some warnings in a set and not others may result in problems. People may assume that the important warnings have symbols and the other parts of the text are less important because they do not have symbols. It may be necessary to use a place-holder icon, such as the alert symbol to serve the role of giving importance to warning texts that do not have a corresponding representational symbol. For complex hazards, accompanying text is almost always needed to give more specific information.

Context

Context provides information about symbol placement and use in the real world (e.g., its associated product or environment). An ambiguous symbol may be clearly understood if seen in its appropriate context (e.g., Horton 1994; Sjoqvist, 2000). It also gives a sense of realism and external and ecological validity that means it is more likely to correspond to comprehension in actual settings. However, many symbol comprehension studies reported in the literature have given little or no contextual information in which the symbol may be seen while in actual use (e.g., Collins, Lerner, & Pierman, 1982; Laux, Mayer, & Thompson, 1989; Leonard, 1994; MacBeth & Moroney, 1994). As a consequence, the comprehension results of these studies are likely lower lower than if the symbols had been shown in context (e.g., Leonard, 2002). In other words, the reason why some symbols may not have performed well in comprehension tests is that they lacked information or cues that would be provided in actual settings of use. Tests without context may underestimate the level of comprehension that a symbol might garner in actual use.

In laboratory environments, giving context might involve a text description or scenario or photographs of the product or environment where the symbol would be placed. Cahill (1975) reported that symbols given with contextual cues were comprehended better than those without context. Wolff and Wogalter (1998) demonstrated that photographic context augmented comprehension rates. Silver, Wogalter et al. (1995) showed that context facilitated comprehension for some

FIGURE 12.14. ANSI-type warning sign that has red color to highlight the radiant heat. (See Color Plate 4).

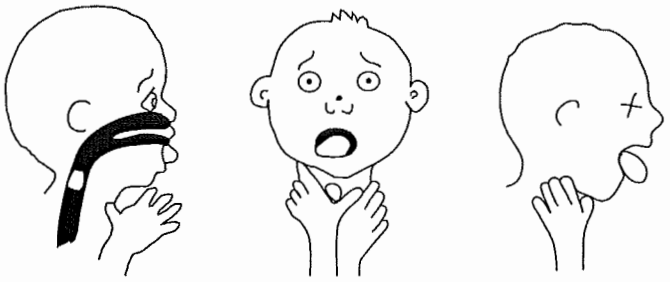


FIGURE 12.15. A sequence of symbols showing a child choking.

symbols but not for others. This result suggests that the quality of the contextual information given may matter. More research is needed on what kinds of context would be beneficial. Greater realism is generally preferred. Immersive three-dimensional environments using software simulation programs may be an approach in this direction (Glover & Wogalter, 1997; Wogalter & Mayhorn, chap. 63, this volume).

Single Versus Multiple Panels

Most safety symbols are single, independent units. However, some complex and abstract concepts may not lend themselves well to simple unit designs (Dewar & Arthur, 1999; Montagne, 1999). For example, in trying to convey the passage of time or a sequence of events, it may be advantageous to portray the overall concept in multiple panels rather than as a single panel. Goonetilleke et al. (2001) found that combining symbols produced better understanding than individual symbols. Morrow et al. (1998) demonstrated that multiple, integrated timeline symbols improved comprehension of a compliance schedule. Research by Kalsher, Brantley, Wogalter, and Snow-Wolff (2000) provided respondents with 15 different pictorial symbols depicting a child choking to be included in construction of multiple panel warnings. Most participants arranged their preferred choking symbol to be a time-sequenced set of three symbol panels. An example is shown in Fig. 12.15. Another example of a grouping of multiple symbols is shown in Fig. 12.16. It apparently means not to use tools and read the manual because there is a rotating fan hazard.

Another aspect of multiple panel presentation is the presentation of both prohibited activities and those that are desired or required (Leonard, 2000). Freeman and Wogalter (2001) also found that respondents improved their comprehension when panels showing both the appropriate and the inappropriate safety behavior was preferred over either alone. For the purpose of showing the appropriate behavior, Leonard (2000, 2002) proposed a pentagon symbol for "to do" operations to complement the circle-slash prohibition symbol. An example of this symbol is shown in Fig. 12.17. The meaning of the pentagon can be learned after only a few presentations (Smith-Jackson, Essuman-Johnson, & Leonard, 2003).

There are potential downsides of multiple panel symbols. Numerous symbols in an area could produce clutter and reduce

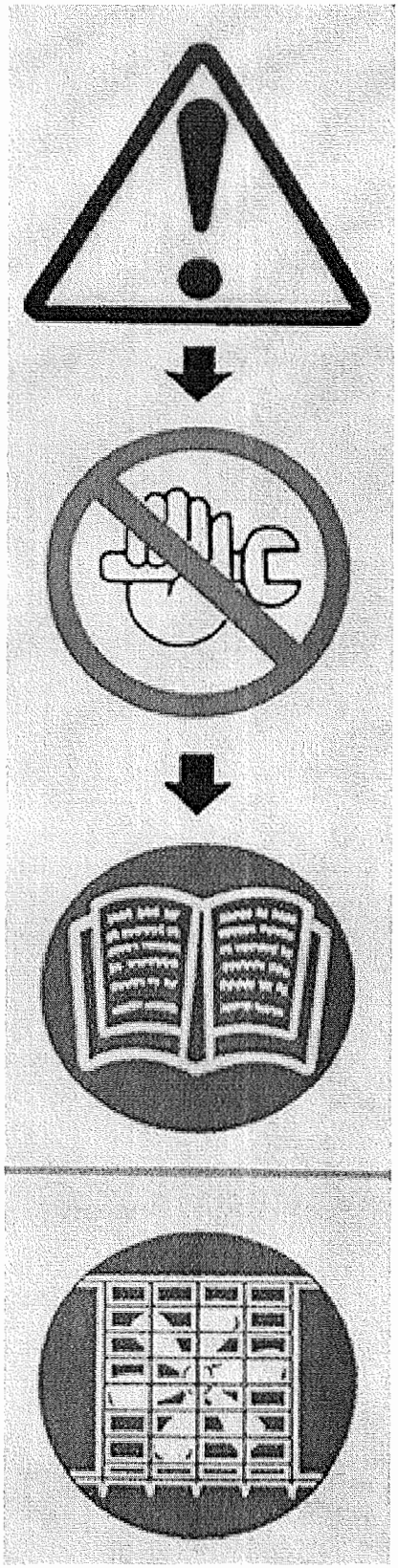


FIGURE 12.16. Multiple symbols panel. (See Color Plate 6).

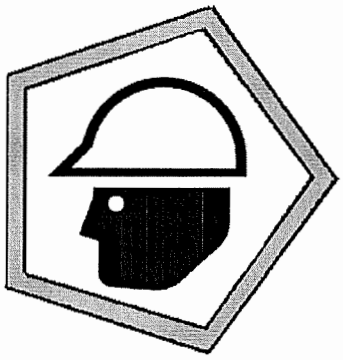


FIGURE 12.17. To-do symbol for wearing a hard hat.

the salience of other more important symbols. In crowded symbol situations, the set may need to be examined with respect to priority. Using prioritization, concepts and symbols are ordered and the most important are given "center stage," whereas others are deemphasized somewhat. A potential methodology similar to that described by Bruyas (1997) might be useful here. It is a subtractive method that first takes a symbol with multiple components and then subtracts the components in a systematic manner to determine their relative importance. Alternatively, an additive method could also be used, going from fewer features composing the symbol to more features. These procedures provide a systematic way of determining which components can be deleted without loss of comprehension while also providing the opportunity to make adjustments to maximize legibility.

While providing a crowded set of symbols is not ideal, not providing needed information is worse. As previously suggested, prioritization will help decrease the crowding. Yet, it may result in people not seeing the lower priority symbols that have received deemphasis. Although individuals may not see a lower priority symbol the first time, they may see them at a later time or someone else could convey the message indirectly. Having the information available for inspection is almost always better than not at all. See Wogalter (chap. 1, this volume) for more on direct and indirect communications and prioritization.

Training

Ideally, symbols would be understandable by everyone. As noted earlier, learning processes are generally easier with symbols that are more representational because there is a concordance between the concept and the symbol. But with abstract concepts and symbols this is less true. Previous experience with other abstract symbols can promote knowledge through which generalizations can be formed and used to comprehend new abstract symbols. However, specific training is usually necessary. Fortunately, it has been generally found to be useful: Low comprehension scores may be upgraded with training. Training in the symbol's meanings can help recall at future exposures to the symbol. Brainard, Campbell, and Elkin (1961) found that comprehension was enhanced once individuals were simply told the meaning of the warning. Cairney and Sless (1982) found that native-born Australians performed better than recent Vietnamese immigrants in an initial symbol comprehension test, but after training with the verbal meaning, the groups were equivalent.

The effect of training may not be a short-term phenomenon. Wogalter, Sojourner, and Brelsford (1997) found high comprehension was maintained at testing conducted 1 week after receiving training. Symbols receiving relatively low scores initially (without training) were dramatically increased after brief training, but some were still below the ANSI Z535.3 standard's criterion of 85% correct. These symbols tended to be abstract depictions of abstract concepts. Lesch (2003) also found that training improved speed of responding and overall comprehension. The magnitude of the training effect was similar regardless of the age of the participant, but older participants had lower overall comprehension rates. In these studies, the training simply involved giving people the verbal meanings of the symbols (short referent—a two-to-four word description) following the initial comprehension test. It is interesting to note that, training involving more elaborate verbal descriptions (more elaborate explanatory statements or scenarios) has not been found in research to produce higher comprehension performance than its associated short referent (Lesch; Wogalter, Sojourner, Brelsford, 1997).

Effects of training have also been shown in a different manner. Leonard (2000) showed that just a few exposures and without specifically stating what the symbol meant, people inferred the meaning of a "to do" symbol apparently by generalizing across several symbols.

Group Differences

Group differences in symbol interpretation have been noted in the literature. A case study about this was reported by Casey (1993). He tells about a medical investigation in Kurd villages in northern Iraq several years back. There had been a severe drought, and the land was parched and could not be seeded. This brought famine and starvation. At about this same time, people began entering hospitals with severe, unknown neurological symptoms. Some died. The diagnosis was eventually mercury poisoning, and after a painstaking investigation, the poisoning was subsequently traced back to grain that had been shipped from the United States. The grain was intended specifically for the purpose of planting crops (not for direct consumption as food). The seeds had been sprayed with a preservative that contained a form of mercury. The grain had been dyed red to indicate that it was unfit for consumption (e.g., in making flour). The onsite investigators discovered that all of the grain cases and bags that were shipped prominently displayed the skull and crossbones symbol for poison as shown in Fig. 12.18. When the Kurd villagers were asked what this symbol meant, they thought it was just an American logo with no particular significance. They did wonder why the grain was red, but that did not stop them from scrubbing it off with water. Unfortunately, some mercury still left in the grain made its way into foodstuffs and was eaten. This example illustrates cultural differences in the recognition of symbols. Not everyone understands even one of the best danger-connoting symbols currently available.

FIGURE 12.18. Skull and crossbones symbol.

As this example suggests, being a member of a class, category, or group can affect whether and how a symbol may be interpreted. As Smith-Jackson discusses in her two chapters on receiver characteristics and culture (chap. 24, 27, this volume), that individuals within demographic groups can have unique characteristics and life experiences that can affect symbol comprehension (Choong & Salvendy, 1998).

Given that many symbols in use today are not well comprehended even by literate persons (e.g., Lim, Kim, & Ko, 2000; Ringseis & Caird, 1995), it is, therefore, not unexpected that special populations (including recent immigrants, older adults, mentally retarded individuals) have more difficulty with symbols. Yet, for individuals who do not have good language skills, symbols may be the only way to convey information in a sign or label.

Cairney and Sless (1982) showed that a group of Australian immigrants poorly comprehended a set of safety symbols, but when trained with their associated verbal meaning, they performed as well as native-born citizens. Smith-Jackson and Essuman-Johnson (2002) found wide variation in interpretation of common symbols by participants in Ghana. Wogalter, Frederick, Magurno, and Herrera (1997) and Smith-Jackson and Wogalter (2000) showed that several common symbols were given different levels of hazard connotation by Spanish and English users. Other studies, however, have noted little or no difference between different language users (Jentsch, 1996; Silver & Perlotto, 1997).

Several studies have reported that older adults comprehend safety symbols less well than younger adults (e.g., Hancock, Rogers, & Fisk, 2004; Morrow et al., 1998; Park, Puglisi, & Sovacool, 1984; Sojourner & Wogalter, 1998). See chapter 26 by Mayhorn and Podany (this volume) for a review.

Individuals with limited cognitive skills would also be expected to have more difficulty with symbolic materials. Hoonhout (2000) and Silver, Basin, Sexton, and Fabbi (1998) found low comprehension rates for individuals classified as mentally retarded. Several studies have also shown that low educational attainment and a lack of symbol familiarity reduces symbol comprehension performance (Mishra & Gupta, 1983). For these groups, special training on symbols' meanings is needed more than for the general public. Another concern is whether certain symbols may be subject to greater levels of misinterpretations by persons with limited cognitive skill. The occurrence of critical confusions errors is the primary concern here (cf. Bruyas, LeBreton, & Pauzie, 1998).

Ideally, symbols should be understandable to all audience segments at risk. In testing comprehension of symbols intended for use across a wide range of targets, it is important to be sensitive to special populations who may have particular problems with interpretation. In particular, it may be necessary to oversample representative users in special groups in testing procedures to ensure misinterpretations are unlikely. In some cases, different populations may require different symbols.

COMPLIANCE

One of the purposes of safety symbols is to foster compliance, in which targets perform the correct safety behavior or avoid unsafe behaviors. The evidence that pictorials enhance behavioral compliance is not particularly clear-cut. Some studies have found no effect of symbols. For example, Schneider (1977) reported that adding a Mr. Yuk symbol (see figure in chap. 18 by Wogalter & Vigilante, this volume) or the skull and crossbones symbol did not significantly reduce the number of preliterate children opening a presumably hazardous container. Friedmann (1988) reported no compliance effect of adding a symbol to text compared to text alone. Using a chemistry task scenario, Wogalter, Kalsher, and Racicot (1993) also failed to show a benefit on compliance rates of adding two symbols on a prominent sign. Wogalter et al. argued that their null result may have been due to ceiling effect because the text-only conditions already had relatively high compliance rates.

However, other studies have found a positive influence on compliance behavior. Otsubo (1988) and Jaynes and Boles (1990) found higher rates of behavioral compliance when symbols were present than when they were absent from the text warning. Part of the reason for the mixed results is that most studies used participants who were capable of reading the accompanying textual material and so the symbols were redundant to information already in the warnings. A potential benefit to literate individuals, symbols add salience and can bolster the text message, but these effects may be relatively small in some cases and, thus, produce the varied compliance findings in the research literature. Had these studies used persons unable to read the English text, there would likely be greater reliance on the symbols and a more dramatic benefit in compliance from the symbols' presence.

CONCLUSIONS

Symbols can be attention getting, aid comprehension, and potentially motivate compliance. Symbols need to be legible and should be designed to withstand environmental assaults on their integrity. Use of open-ended questions is the preferred method of evaluating, symbol comprehension. Symbols may be particularly beneficial for certain groups of people (e.g., people unfamiliar with a language) but also may be less useful for other

groups (e.g., older adults). Symbols that are bold, have high contrast, simple in form, and closely represent the concept intended are usually better comprehended than symbols not having these characteristics. Relatively quick and simple training can aid comprehension performance. Multiple symbols may be useful when a single symbol is insufficient to communicate the complete message by itself. Even if a symbol is not comprehended, it can serve to attract attention to other aspects of a warning. Misinterpretations, particularly critical confusions, should be avoided. Although symbols hold a great promise for communicating safety information, some of the associated difficulties should be considered in their application.

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