CHAPTER EIGHT

Comprehension and Memory

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The factors related to the comprehension and memory of warnings are described. One of the main purposes of warnings is to inform. Warnings can help to fill in gaps of knowledge about potential 'hidden' hazards. Warnings should be understandable and sufficiently explicit so that persons at risk will be informed about the hazards and potential consequences if they fail to comply with its directives. The design of prototype warnings based on research and guidelines is described. Prototypes need to be tested to assure that the intended target population attains adequate understanding. Features comprising the warning's physical characteristics can provide an overall hazard impression which is important if the warning's specific message is not completely understood. Additionally, factors that affect comprehension and memory of warning information (e.g., familiarity, habituation, and training) are described. *Note: Figures that do not appear in the text of this chapter are shown in the color plate section.*

8.1 INTRODUCTION

Chapter 7 by Wogalter and Leonard concerned the factors that affect the capture and maintenance of attention. The present chapter concerns the next stage of processing, involving the factors that produce comprehension (understanding) and memory.

This chapter covers many topics, and we have organized its presentation in the following way. It begins with a description of how information processing theory can be used to describe the processes involved in acquiring hazard/warning knowledge, and how memory is activated and reactivated based on cues provided by warnings and their context. The next three sections describe the factors affecting the comprehension of printed textual messages, symbols, and auditory warnings. In these sections, the literature is reviewed from which general principles are drawn. These general principles may be applied in the initial design stages to produce a set of preliminary prototype warnings. We then describe

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why it is necessary to test the warning prototypes for comprehension. We then discuss the factors that influence acquisition of information and skills (learning and training). We then turn to a discussion on how the warning's physical characteristics can provide a general hazard impression. Finally, the topics of familiarity, habituation, and prospective memory are discussed. The chapter closes with a brief summary and recommendations.

8.2 KNOWLEDGE AND AWARENESS

One principal purpose of warnings is to inform people about hazards. If the hazards are already known and people are aware of them, a warning containing the same information probably is not necessary. For example, it is not necessary to label a kitchen knife that it could cut skin or a pencil that it could puncture the eye. These are common, simple items for which the hazards are obvious to nearly everyone. The exception, of course, is young children's lack of understanding of these facts, but we assume that care givers will protect them until they are old enough to learn this information and handle these tools properly.

Nevertheless, people do injure themselves with knives and pencils—even though the injured person knew an event of this type could occur. In the USA, industrial maintenance personnel are trained to disengage the power when repairing equipment. Yet many workers are injured every year when they fail to lock out the power properly to the machinery that they are repairing. Most of the injured persons had been trained on lock out procedures and 'knew' what to do (i.e., the information was in memory), but they 'forgot.' These instances of 'forgetting' are due to people not being conscious or aware of the relevant hazards at the proper moment. Therefore, warnings not only serve to inform (to get the information into memory), but they can also serve as reminders, or cues, that activate existing knowledge in memory so that people are more likely to be aware of the hazard at the time they are at risk. We will have more to say about this reminder or cuing role at various points in the chapter.

8.2.1 Knowledge Gap and Acquisition Theory

Before the technological revolution, most hazards associated with the tools that people used were obvious and apparent. Technology has brought to the market new products that are not obvious to set up/install, use, maintain, or repair. They have 'hidden' (nonapparent or latent) hazards. For example, one can not tell the effects of a white pill just by its appearance. Also, it is not obvious that automobile air bags could cause serious injury or death if a person sits too close to them during their deployment. In both examples, warnings are needed to inform people about latent hazards, allowing them the opportunity to exercise appropriate precautions. **Figure 8.1 (see color section)** shows a warning sticker sent to registered owners of vehicles with air bags.

For a person to be adequately informed, he or she must comprehend the hazards, know how to avoid them, and know the potential consequences of unsafe behavior. Frequently the person's knowledge is incomplete, particularly for nonapparent hazards.

If there is a gap in knowledge, the warning should be designed to induce formation of new memory structure so that the person's knowledge becomes consistent with the hazard-related knowledge needed. Generally the assimilation of new information will be easier if extensive relevant memory already exists (i.e., a smaller knowledge gap) than if very little related memory already exists (i.e., a larger knowledge gap). Formation of new memory generally requires effort, and such effort uses mental resources. Because people may be occupied with other tasks that are absorbing some of their mental resources at any given time, the warning should be constructed so that the information being transmitted is easy to grasp and does not overload the system.

When only a relatively small portion of the warning information does not match, the gap in knowledge is relatively small. Here there is less information to assimilate than if a large knowledge gap existed. Producing new memory when there is a small gap requires less mental resources. The processing to reduce or close a small gap can be accomplished more readily than when a large gap exists; in the latter case the formation (accommodation) of considerable quantities of new information into memory is needed.

Generally, a warning that is easier to process is more effective than a warning that is more difficult to process. Thus, warnings that have as their basis information that the person already knows are almost always better than warnings that contain large amounts of incongruous (nonmatched) information with respect to the person's existing knowledge. Warnings that contain easy-to-grasp information are particularly beneficial when warning exposure time is short, when quick reactions are necessary, or when the individual is fatigued or stressed.

Another reason why warnings should be well matched with what people already know is that people are 'cognitive misers.' They do not want to expend considerable amounts of time and energy to fill large knowledge gaps.

Some of the above description is related to the concept of schema (or script). Schema theory suggests that individuals can develop complex mental structures regarding various topics (e.g., Rumelhart, 1980). A schema includes information from previous experiences that guides people's expectations about various situations. A schema about cooking dinner using a charcoal grill might include such things as cutting up the food, starting the coals, and applying sauce. This schema could also include the possibility of being burned by touching the hot grill or by flying sparks. Thus, based on a schema about the nature of the grill and how hot it gets, the cook might wear a mitt on one hand and avoid touching the grill with the other. However, there are other safety concerns that this person might need to know to accomplish the barbecuing task safely. For example, individuals might not know that burning coals produce carbon monoxide. Accumulated colorless and odorless carbon monoxide can deplete the oxygen supply to the brain. This is a lesser-known (non-obvious) hazard. The reason this information is not well known is due partly to its physical characteristics and how it affects the body and partly because most grilling occurs outdoors where there is sufficient ventilation to disperse the gas. However, to a company that manufactures grills, it should be foreseeable that some people will attempt to use their grill indoors in bad weather. Therefore, it is important to warn against using the grill in an enclosed space. A warning for the grill's heat hazard is probably less important than a good warning for the carbon monoxide hazard, because high temperatures are an obvious inherent feature of cooking on charcoal grills, but this is not true for the carbon monoxide hazard.

8.3 UNDERSTANDING TEXT

8.3.1 Language

For text-based warnings, it is obvious that in order to convey the message, the individual must have some knowledge of the language to be able to read and understand the warning.

Individuals who know only Spanish probably will not be able to understand warnings written only in English (although some 'foreign' words might be cognates of terms in a language the individual knows; Wogalter, Frederick, Magurno, and Herrera, 1997a). If the target audience in a particular geographic area is comprised of persons knowing distinctly different languages (not a common one), then the warning might need to be presented in more than one language. Obviously this would benefit these groups but there are also some negatives. One is that there may be limited space, and by giving more space to translations, the space available for the primary language is reduced, together with the print's prominence and legibility.

In Chapter 7 by Wogalter and Leonard we touched on the multi-language problem. One solution is to use label designs that increase the space available for warning materials. In a market comprised of a mixture of English-only users and Spanish-only users, one strategy is to present both languages equally sized on a label (label is split in half). Another potential method is to size the print based on the percentage of people in a population who use the language. For example, if in a particular consumer market 70% understand only English and 15% understand only Spanish (and 15% fitting other categories), then the English portion might be made somewhat larger and the Spanish portion somewhat smaller (although not necessarily proportional to exact population percentages). In many cases, it may not be practical to print other languages. At issue is whether it is acceptable to allow people to go unprotected when the safety instructions are not presented in a language that the user understands.

Another strategy is to include translations of only the most important information. Most of the label would be in the primary language, but space would be allocated for a short message in other language(s). The short message might present (a) the main dangers, (b) a statement that emphasizes that before using the product seek an accurate translation of the warnings and instructions from someone, and (c) an easy way to contact a multilingual representative of the manufacturer by phone, mail, or internet.

As we have seen, the issues involved in the multi-language problem are complex. A whole host of practical and societal issues must be considered. While there are no definitive solutions, it is clear that the warning designer must consider language-usage by persons exposed to the hazard.

Not only do people differ in terms of the specific languages they use, but also with respect to their skills and competence in using their primary language. The design should consider people with low literacy levels, with low verbal comprehension skills, or with limited education.

Warnings should be designed so that at-risk individuals will be able to acquire the necessary information to keep them safe. Unfortunately, this is not generally the case. Usually warnings are written by people who are more educated and knowledgeable about the to-be-communicated hazards than the individuals that comprise the target audience. Warnings designers can make the mistake of assuming that everybody knows what they know. This assumption may be correct some of the time, but it may be incorrect with respect to some particularly critical safety information. Incorrect assumptions can produce errors when important information is left out or terminology is not understood or misunderstood by target users. One example is material safety data sheets (MSDSs) which must be available to workers in all workplaces using hazardous chemicals as required by the US Occupational Safety and Health Administration (29 CFR 1910, Hazard Communication Act). MSDSs are intended to describe the hazardous nature of the chemicals that the workers work with. Unfortunately, often these documents are extremely technical and fail to do their intended job with this audience.

Table 8.1 Mean expert-judges' quality ratings of lay participants' explanations and recommended actions for warning terms (adapted from Leonard *et al.*, 1991).[a]

Warning term	Explanation	Recommended actions
Flammable	1.19	1.66
Poison	1.67	1.63
Combustible	1.16	1.27
Irritant	1.20	1.26
Explosive	1.27	1.13
Corrosive	0.87	0.92
Dangerous when wet	1.00	0.80
Radioactive	0.68	0.74
Spontaneously combustible	1.05	0.58
Oxidizer	0.30	0.37

[a] Note that quality ratings are based on a scale ranging from 0 (poor) to 3 (good).

Another related problem is that some of the words in warnings can be interpreted differently by different people. This variability indicates that some people's beliefs are incorrect. The technical definition of 'flammable' is a substance that has a flash point of 100° Fahrenheit (about 38° Celsius) or lower (as defined in US Federal Regulations). Lay persons are not likely to be familiar with this technical definition and may interpret the term quite differently (cf. Leonard, Creel, and Karnes, 1991). In fact, research by Main, Frantz, and Rhoades (1993) showed that many lay persons interpret 'combustible' as being more hazardous than 'flammable' when actually the reverse is true—according to formal, technical definition (in Federal rules). Perhaps lay persons believe that 'flammable' means the substance will burn like a match, whereas 'combustible' sounds like an explosion.

Laughery (1993) describes several instances where manufacturers have made incorrect assumptions about what targets know. Vigilante and Wogalter (1996) note that domain experts and non-experts differ in their conceptions of which warning components are most important. Research by Leonard and his colleagues has shown that only a small proportion of people accurately understand some of the most commonly used terms in warnings (Leonard *et al.*, 1991; Leonard and Digby, 1992). Table 8.1, adapted from Leonard *et al.* (1991), shows expert judges' ratings of a set of definitions produced by lay persons for several commonly used hazard terms. Ideally, there should be a match between the intended meaning of the term and the target population's understanding of it. As can be seen in the table, the match is not very good for many of these terms. For example, the term 'oxidizer' is poorly understood. However, this term may be rich in information for technically trained persons such as chemists or firefighters, activating a considerable body of existing knowledge about the nature of the hazard, and what to do to avoid negative consequences. To trained individuals, the term 'oxidizer' is probably an adequate warning. The problem is that most lay persons do not know what this term means. It does not cue knowledge on the kinds of precaution needed to prevent harm. Thus, a warning intended for the lay public needs to include terms that cue knowledge that ultimately leads to proper hazard avoidance. In the case of 'oxidizer' hazards, such information might include the potential for fire, explosion, and extreme injury. As noted earlier, technically trained persons can mistakenly believe that they know what the target audience knows. It is therefore critical to determine whether the target audience interprets the intended message properly. Also attention needs to be focused on the possibility that some people may misinterpret the message, and if so, to determine how the misinterpretation can be reduced.

8.3.2 Vagueness of Terms

Another terminology-related problem is vagueness (cf. Kreifeldt and Rao, 1986). The commonly used warning phrase 'Use in a well ventilated area' can be interpreted in many ways. The problem is that it does not tell what specific conditions are safe and unsafe. If the product is used inside, how big should the room be? Is a room with one open window adequate? Should you use a fan? A respirator? Clearly more explanation is needed than this statement provides.

Consider another phrase found on many consumer-product labels: 'Do not use near an open flame.' By itself, this phrase is inadequate for three reasons. First, it does not tell what 'near' means. Second, people may not realize that pilot lights in gas stoves, furnaces, and water heaters are 'open flames' in the technical sense. Third, people may not realize that the pilot light can be 'on' even if the appliance is 'off.' Extremely serious injuries have occurred because people did not think about pilot lights. Some people may not even realize they exist. Others may know of their existence but do not think of them as 'open flames' as usually they are located inside an enclosure and not readily visible. Other potential spark sources include common electric devices such as on–off switches, telephones, and electric motors. We suspect that people often do not think of them as sources of ignition.

Both example statements mentioned above need improvement. In particular, they need to be more explicit (i.e., to give more specific information) so that people have the opportunity to be made fully aware of the hazards, consequences, and what they need to do. Explicit warnings are better able to fill the knowledge gaps that we discussed earlier. A warning for a flammable product used by the general public needs to provide information about (a) the potential of fire and explosion hazards when used in the vicinity of ignition sources, (b) where potential ignition sources might be located, and the possibility that there might be more spark-producing sources in their environment, (c) the distance from these ignition sources that is safe, (d) how vapors may accumulate and travel, and (e) what kind of ventilation conditions are appropriate and inappropriate. Explicitness can apply to describing the nature of the hazard, instructing what to do and not do to avoid the hazard, and telling about the consequences if the instructions are not followed. Obviously this is a lot of information, but the amount could be reduced by determining what people already know. Which parts of the warning need to be explicit depends on the hazard and foreseeable use situation. While the consequences associated with oxidizers and flammables need to be explicit, the consequences associated with a wet floor hazard do not. In the latter case, an abbreviated sign is sufficient to cue most people's existing memory that slippery floors can cause falls. Unfortunately, many potentially hazardous products have warnings containing vague, non-explicit information that fail to reduce knowledge gaps adequately.

One reason that has been given for the lack of explicitness in most consumer product warnings is that manufacturers avoid them because of the belief that explicit warnings will deter people from purchasing their product, compared to a competitors' product with a less explicit warning. However, published evidence supportive of this assumption is not strong, and indeed, equivocal at best. Some studies have found that explicit warnings produced negative attitudes (Morris and Kanouse, 1981; Vaubel, 1990; Vaubel and

Brelsford, 1991), whereas other studies have found no effect (Laughery and Stanush, 1989; Silver, Leonard, Ponsi, and Wogalter, 1991) or even a positive effect (e.g., Ursic, 1984) on product preferences and purchase intentions. In finding a positive effect of explicitness on perceptions, Ursic (1984) suggests that explicit warnings reduce people's uncertainty, making people feel safer. The effects of explicitness probably depend on the type of product, the consumer, and the specific warning. Explicit warnings for dangerous tools like gas powered lawn mowers or wood shredder-mulchers are less likely to reduce sales than explicit warnings for a product that is expected to be safe, like hair spray. Also, it is not unreasonable to expect that certain large segments of the population might prefer products with more explicit warnings so that others in their household (e.g., their spouse, older children, caretakers) would be informed.

8.3.3 Inferences

As indicated earlier, development of understandable text should consider the kinds of inference that must be made by readers (Kintsch and van Dijk, 1978). Incorrect inferences could cause comprehension and recall to suffer (Britton, Van Dusen, Glynn, and Hemphill, 1990). Therefore, the warnings designer should avoid text that requires extensive inferential processing because the inferences might be wrong.

Nevertheless, some inferences will need to be made based on the need to keep warnings brief. Activation of existing information in memory through good warning cues will increase the likelihood that correct inferences will be made. The problem is that vague, highly technical, or incomplete warnings may not activate the appropriate kinds of knowledge, leaving the individual to make use of more limited information, leading to the possible production of incorrect inferences.

8.3.4 Underlying Concept

People may also have difficulty with the underlying concept to be communicated. For example, to understand the concepts of radiation and biohazard fully, extensive education and training are required. Therefore, it is unlikely that a brief textual message will be able to convey all of the hazard-related ramifications. Obviously trying to convey concepts about which people have little existing knowledge (i.e., large gaps of knowledge) is difficult. A related issue here concerns how much information should be communicated. Despite knowing that there is a large knowledge gap, and knowing that one would like to communicate to users all relevant information about the hazard, consequences, and instructions, there is, however, another important issue to consider: people might not be willing to read an extremely long message, but would be willing to read a shorter message. Therefore some tradeoff decisions may need to be made which could involve the use of a shorter on-product label, and a longer, more complete set of warnings and instructions elsewhere. Later in this chapter, we discuss alternative ways that a warning by its physical characteristics can relay some hazard information just by the way it looks (or sounds).

8.3.5 Readability

Another factor associated with warning text comprehension is readability. Readability refers to the ease with which one can extract information from a text message. This term, however, is sometimes used inappropriately to mean legibility. As described in Chapter 7 by Wogalter and Leonard, legibility refers to the ability to discriminate the component elements of the printed alphanumeric characters or parts of pictorial symbols. The goal of making a warning 'readable' is to make the text message simple, direct, and easy to understand.

Readability can be determined in several ways. One is to use a readability index, such as the one developed by Flesch (1948). Klare (1976) and Duffy (1985) review other similar indices. Most give a numerical estimate of the approximate grade-level reading skill required to understand the material (or the percentage of the native English-speaking audience that would be expected to understand it) based on such factors as the number of letters in the words and the number of words in sentences. If the textual material is intended to reach a large percentage of the general public, some authors have suggested that it should be written somewhere between 4th and 6th grade level. How these particular grade-level guidelines were determined is not known, but probably they are fairly good guideposts when producing text warnings for the general public.

The readability indices were not developed for evaluating warning text. There are three problems associated with using the currently available readability indices in evaluating warnings. One is that most readability indices require text samples of at least 100 words, whereas most posted warning signs and product labels are usually fewer than 100 words. However, there are many kinds of warning material with more than 100 words that would not have this problem, e.g., employee-safety training manuals, product manuals, and package inserts. A second problem is that warning text frequently lacks the punctuation necessary for the readability indices to parse clauses and sentences. Silver *et al.* (1991), however, demonstrated a method for compensating for these problems by duplicating the shorter warning text until it exceeded 100 words and then adding punctuation. The third, and perhaps the most serious problem with readability indices, is that they do not fulfill their main intended purpose of measuring how well people understand the material at the grade-levels or percentages they supposedly predict. For example, most of the readability formulae assume that all shorter words and sentences are more understandable than longer ones. This is true in a general sense, but using shorter words and sentences will not automatically enhance understanding. It is possible for a readability index to indicate that some sample of text is understandable by fourth graders, yet the specific words or syntax used might render the message quite difficult to understand (cf. Chapanis, 1965). Even if the individual words of a warning message are understandable, the words as a group might not be. Note that scrambling the words within phrases and sentences would give the same readability score as real sentences. Until readability indices become more sophisticated, in particular by being capable of evaluating the semantic content and context, they should be used only as a rough guide in evaluating textual warnings, and should not be treated as a reliable or valid tool for assessing warning comprehension. As we will discuss later, the only good way to know whether the material is understandable is to test it on the target population.

8.3.6 Organization

Another approach to facilitating the understanding of warning text is through the material's organization. Information structured coherently is better than a random organization. Organization can be produced in several ways, such as a hierarchical structure, in a network, and/or based on mental models. Kozminsky (1977) found that providing titles (or headings) consistent with the to-be-learned information improved memory. Desaulniers

(1987) has shown that the use of outlines, lists, and hierarchical arrangement of concepts improves its perceived organization. However, research on which kinds of organization maximally benefit knowledge acquisition has been to date quite limited and is a research area that could provide useful design guidance.

8.3.7 Guidelines

Some attempts have been made to provide rules and guidelines for producing clear writing. Hartley (1994) describes a set of guidelines for designing instructional text that appear to have applicability to warnings. Also, general rules for constructing warning text can be found in the ANSI (1991, 1998) Z535 warning standards, and in the Westinghouse Electric Corporation (1981) and FMC Corporation (1985) guidelines. The guidelines usually specify, for example, that the text should be brief and written in common, nontechnical terms when the target audience is the general public. These guidelines are probably good starting points when designing warnings. However, they are not always applicable to the specific situation or message to be communicated. Moreover, there is such an abundance of rules and guidelines, that applying them may be difficult (Wright, 1985). Compromises frequently have to be made between different design rules. For example, consider the guideline that we gave earlier regarding explicit wording: research has shown that explicit warnings can benefit comprehension. However, following this rule produces longer warnings and conflicts with another guideline that warnings should be brief. Currently, there is very little research that delineates which guidelines are relatively more important and how conflicts should be resolved.

8.3.8 Limitations of Guideline Factors

Thus far we have discussed several factors that can influence the understanding of warning text. These factors included: explicitness, readability indices, inferential analysis, organizational approaches, and use of guidelines. They can be used to develop initial prototype warnings designs. However, their use as the sole method of establishing and constructing a warning has an important limitation, which is that they can allow the production of warnings that are not as understandable as they could be. The only way to know the extent of understanding is to actually test a representative sample of the target audience. We will have more to say about this topic later in this chapter. Further information on comprehension testing is also given in Chapter 3 by Young and Lovvoll. In the next section, we consider another way of conveying hazard information using nonverbal (non-textual) symbolic representations.

8.4 UNDERSTANDING PICTORIAL SYMBOLS

An increasingly common approach in warnings design is to use pictorial symbols as an addition or substitute for words (Dewar, 1999). Symbols might depict the hazard, the consequences, actions to take or not take, or some combination of these. Well designed symbols can be useful for illiterates as well as literates who are not skilled in the particular language of the printed text message, for example travelers in foreign countries. Symbols can serve not only to enhance comprehension but also, as described in Chapter 7 by Wogalter and Leonard, symbols can also help to capture people's attention.

8.4.1 Symbol Processing

Generally, pictures are easier to remember than words; sometimes this is called the picture superiority effect (Nelson, 1979). One explanation of this effect comes from dual-code theory (Paivio, 1971, 1986). Two types of coding system in memory are hypothesized: verbal and imaginal (visuo-spatial). Words are assumed to be coded verbally, and pictures are assumed to be imaged. Each code can evoke the other code, but the translation from code to code varies in difficulty. Some words can easily evoke specific concrete images (e.g., 'gloves,' 'goggles') while other words representing abstract concepts (e.g., 'protective equipment,' 'security') are not as readily translated into mental images. High imagery words may activate both codes, which makes encoding into memory more effective and subsequent retrieval easier. This information is easier to retrieve because theoretically more 'paths' are created in memory, making the information more accessible (more likely to be cued) at later times. Thus, according to dual-code theory and the picture superiority effect, warnings with symbols should be more effective in terms of encoding and retrieval.

8.4.2 Comprehension Testing

Therefore, symbols appear to have considerable potential in communicating hazard-related information. The best symbols can convey concepts quickly and readily activate considerable pre-existing hazard knowledge. Ideally, symbols should be understood by everyone, but in most cases they are not. The research literature shows symbol comprehension rates can vary from very high to very low, depending on the symbols, the test methods, and the population tested (e.g., Laux, Mayer, and Thompson, 1989; Calitz, 1994; Leonard, 1994). Since we know that some pictorials will not be understood by some percentage of the at-risk population, a question that could be asked is: what level of comprehension is acceptable? Published standards have attempted to address this issue by quantitatively defining what constitutes an acceptable symbol. The American National Standards Institute (ANSI Z535.3, 1991, 1998) requires that 85% or more of the answers from at least 50 people should identify correctly the referent concept with no more than 5% critical confusion. Critical confusion comprises answers opposite to the intended concept or wrong answers that could lead to behavior that could result in injury or property damage. Obviously, critical confusion errors are to be avoided. As an example consider the symbol in Figure 8.2. It shows a side-view, outline shape of a pregnant woman with a circle-slash prohibition. The intended meaning is that women should not take the drug while pregnant or, if they are not pregnant, to take precautions to avoid getting pregnant while taking it. However, this symbol by itself can also be interpreted to mean birth control protection, a potentially disastrous error. Obviously, it is very important to limit the number of cases of critical confusion. Avoiding them is even more important than high comprehension scores.

According to ANSI Z535.3 (1991, 1998), when a safety symbol can not be developed that reaches the 85% criterion, then text must accompany it. In the unification of countries comprising the European Union (EU), people will freely traverse borders where they do not know the primary language. The EU's international symbols are intended to be displayed without any accompanying text. The Organization of International Standards' 3461-1 standard (ISO, 1988) requires 67% correct identification in a comprehension test.

Attainment of the benchmark comprehension score does not mean that the symbol in question is adequate, nor does a lower score indicate that it should not be used. The

Figure 8.2 Warning symbol meant to indicate that a drug for severe acne should not be taken by pregnant women. Some women have apparently interpreted this symbol to mean that the drug acts as a contraceptive, illustrating a critical confusion. This symbol appeared in the *FDA Consumer* (**22**(8), p. 26), US Food and Drug Administration, Rockville, MD.

ultimate criterion is: does the symbol/pictorial improve safety? If no better pictorial can be made and the critical confusion rate is low, it is better to use the symbol than not to use it.

The validity of the above-mentioned criterion notwithstanding, relatively few symbols in use today have been tested. In the tests that have been conducted, the results often show that many pictorial symbols in current use have low comprehension rates. Even symbols that we would expect to produce high identification rates are not understandable by substantial numbers of people. Leonard (1994) found that both college and English as a second language (ESL) students failed to recognize many symbols used commonly in transportation. Collins and Lerner (1982) found that many individuals had difficulties understanding some of the symbols used for fighting fires. Calitz (1994) found that symbols used in South Africa by legal mandate were poorly recognized. In addition, less than half of a set of automotive-related symbols were named correctly by 60% or more of the respondents in a study by Jack (1972). MacBeth and Moroney (1994) found that college students had difficulty in correctly interpreting several ISO symbols. Laux *et al.* (1989) and Ringseis and Caird (1995) both found that although some industrial safety and pharmaceutical symbols are comprehended well, others are not. In the next several sections, we discuss some of the reasons why symbol comprehension can be poor.

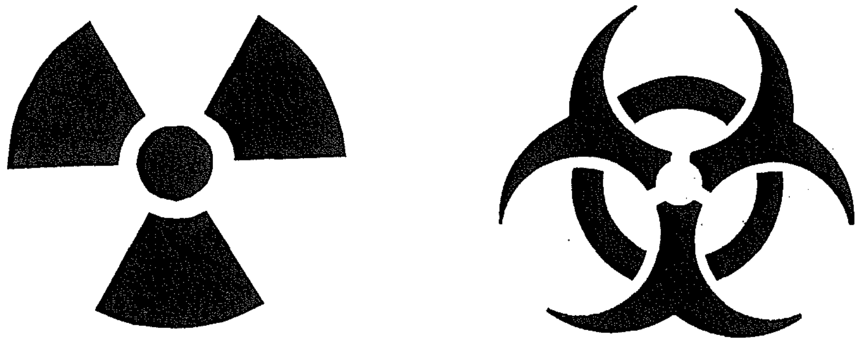

Figure 8.3 Symbols for (a) radiation and (b) biohazard are abstract representations; they do not directly represent the specific physical nature of the hazards.

8.4.3 Underlying Concept

As with text messages, people can have difficulty understanding the underlying concept that a pictorial symbol is supposed to represent. The symbols in Figure 8.3 for radiation and biohazard are two examples. Symbols for these concepts are abstract and are depictions that do not closely represent the actual physical entities. Even if the people are trained (or learn) the short referent definition associated with a symbol, the individual might not really know the nature of the intended concept, its implications for health and safety, and what he or she needs to do to avoid being hurt. Thus, as was true for textual messages, it cannot be expected that a symbol by itself will be able to convey all of the safety ramifications for complex, abstract concepts.

8.4.4 Visualizability

When the depiction bears resemblance to the actual visual objects or procedures, then in general understandability will be greater. However, some phenomena are not visible to the eye and are difficult to depict as visual images. Examples include two hazards that we have already mentioned, radiation and biohazard (Figure 8.3). Other difficult-to-depict examples include carbon monoxide, time, and beach undertow. Dewar and Arthur (1999) describe some of the difficulties of creating a pictorial display that illustrates the concept of undertow. The pictorial symbol was intended to convey that there may be strong water currents that could pull people under water. Another (usually) invisible concept, electricity, does have a reasonably successful symbol (the jagged arrow shock symbol shown in Figure 8.4), but undoubtedly it is based on (a) the shape being similar to one visible form of electricity, lightning, (b) that most people have received some home and school education that electricity can be dangerous, and (c) the symbol's frequent use.

Lack of visibility is important also with respect to the symbol itself. As mentioned in Chapter 7 by Wogalter and Leonard, sometimes the slash in the circle/slash prohibition symbol can reduce identification rates by obscuring critical components (Dewar, 1976; Murray, Magurno, Glover, and Wogalter, 1998). Figure 8.5 shows a prohibition symbol that hides a critical component necessary to understand the symbol. Does it mean 'Do not walk' or 'Do not stand'? This prohibition symbol was taken from an actual warning intended to caution people about an 'automatic' door that can close unexpectedly when the system does not detect a person in the doorway threshold. Therefore it was intended

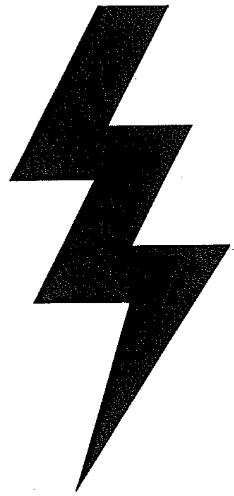

Figure 8.4 Symbol for electricity.

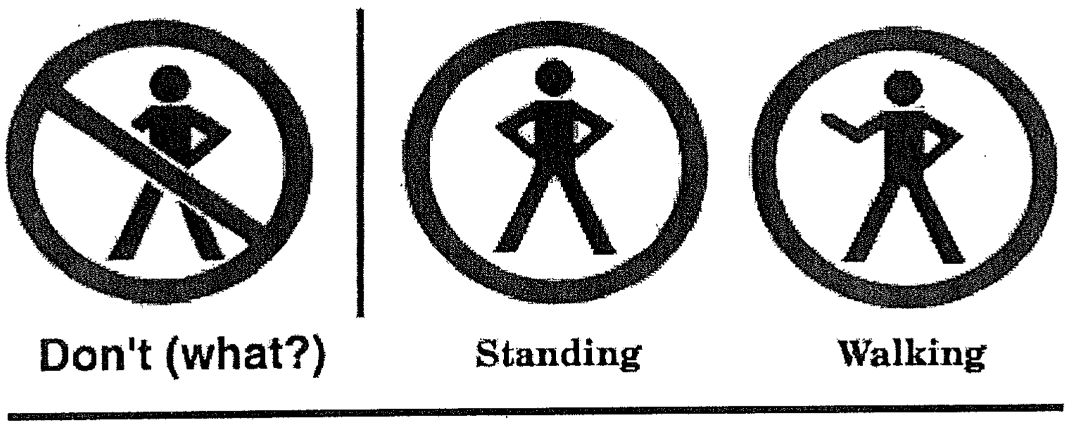

Figure 8.5 Ambiguous prohibition symbol. Does it mean 'Do Not Walk' or 'Do Not Stand'? The slash obscures a critical portion of the symbol, producing the possibility of a critical confusion. (It was used for a sign on a set of doors that open automatically when a person approaches them. Unfortunately the sensor system did not work well when a person was standing in the threshold and the door could close unexpectedly. In this case, the symbol was intended to mean 'do not stand').

to mean 'Do not stand' (to keep moving) when it can also be interpreted to have the opposite meaning, 'Do not walk'—a clear cut critical confusion. Bruyas (1997) has explored several methods of measuring the relative importance of components comprising graphic symbols. Such procedures could be useful in determining which types of component can be deleted without loss of comprehension performance, and at the same time, reducing clutter and increasing legibility. Also, critical components of complex pictorials could be highlighted to distinguish them from less important details (Brantley and Wogalter, 1998).

8.4.5 Quality and Form of the Depictions

The quality of the artwork can affect comprehension levels. Numerous design guidelines exist on how to produce professional quality symbols (FMC Corporation, 1981; Westinghouse Electric Corporation, 1985; ISO, 1988; ANSI, 1991, 1998; Sanders and

McCormick, 1993). Many of the basic design guidelines derive from the perceptual principles of Gestalt psychology (see, e.g., Coren and Ward, 1989; Sanders and McCormick, 1993). These characteristics include figure–ground, simplicity, contiguity, boldness, similarity, among others. Generally, pictorial symbols with good contrast and comprised of simple forms are preferred. See Dewar (1999) and Sanders and McCormick (1993) for more information on this topic.

For any concept, many drawings are possible. The depiction of a warning concept might focus on the hazard, the consequence, the compliance instructions, or some combination of these. In addition, the objects in the symbols can be variously depicted in different perspectives, by different amounts of detail and emphasis, etc. Sometimes a minor change to a single component of a symbol can change its meaning dramatically. Several authors describe some of the issues involved in creating and refining symbols (e.g., Wolff and Wogalter, 1993, 1998; Dewar, 1999; Magurno, Wogalter, Kohake, and Wolff, 1994). Zwaga (1989) and Brugger (1999) discuss methods for reducing a large set of depictions to a few good potential symbols that can be verified by comprehension testing. We will have more to say about symbol comprehension testing later.

8.4.6 Literal Interpretation

A common pictorial symbol for 'No open flames' is a circle/slash overlying a lit match. The literal meaning of the symbol is that no matches should be lit in the area. However, this same symbol has also been used as a signal that *all* ignition sources (including spark generating devices) must be extinguished because flammable substances are present. It is apparently being assumed that people will extract from this and other flame symbols the broader concept of ignition source. The problem is that although some people may make this extended interpretation, many people will make only the literal interpretation. It really cannot be expected that everyone will generalize to the broader concept without additional accompanying information or specific training.

8.4.7 Complexity

As noted previously, simple symbols are preferred. However, one cannot always follow this guideline when trying to produce an understandable symbol. Consider again the concept of 'no ignition source.' Possible depictions of this concept include a lit match (as described before) or just a simple flame overlaid by a red circle/slash prohibition symbol. However, neither of these symbols conveys the full concept. Therefore, it might be necessary to include other forms in the symbol, such as perhaps, electrical switches and telephones—two common devices that produce sparks. However, including these or other objects increases the detail and complexity of the symbol which could have negative effects (e.g., decreased legibility). Thus, while we would like to make simple symbols, we can not always do so and still be confident that all persons will understand the full intent of the message.

8.4.8 Single versus Multiple Panels

For some concepts, a single symbol panel may not be enough. Some symbol designers (e.g., Dewar and Arthur, 1999; USPC, 1997) have used sequences of symbols or multiple

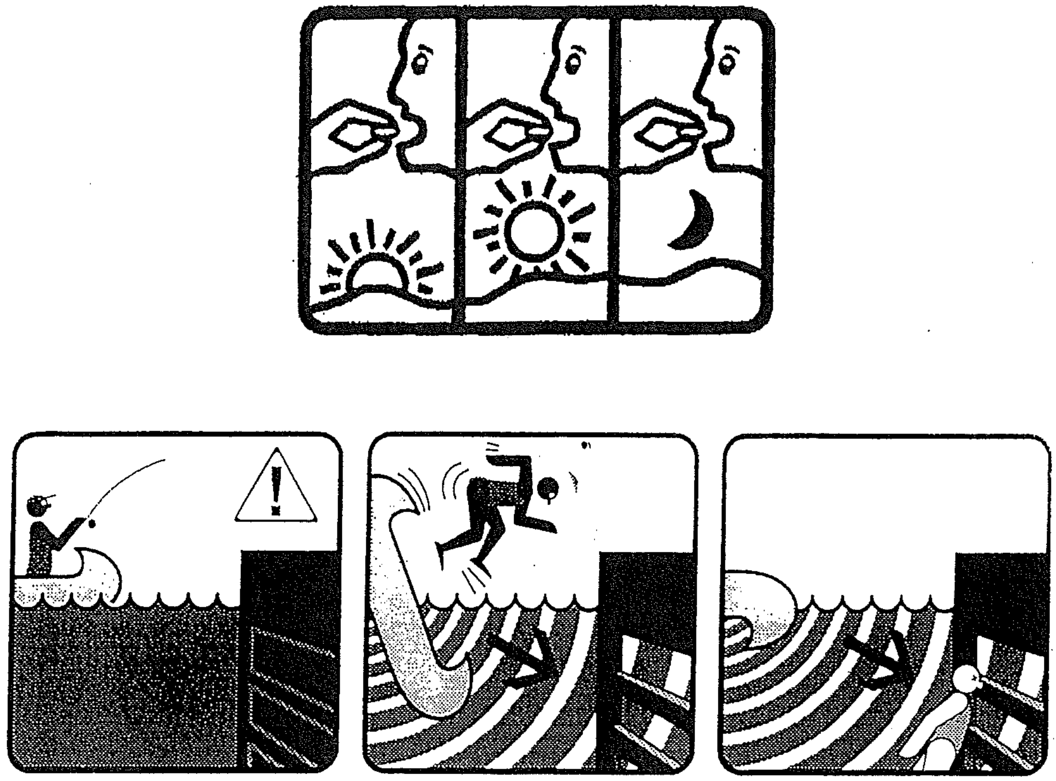

Figure 8.6 Example symbols requiring multiple panels to convey a concept ('Take morning, noon and night' and 'Undertow').

panels to convey certain concepts. Figure 8.6 shows symbols meant to represent the concept of 'Take morning, noon, and night.' The other symbol is for 'Undertow.' One can see that adequate depiction requires more than one panel.

8.4.9 Language Accompaniment

Symbols and language can complement each other (e.g., Cairney and Sless, 1980; Morrell, Park, and Poon, 1990; Young and Wogalter, 1990; Sojourner and Wogalter, 1997, 1998). People who do not understand a pictorial might be able to read accompanying text. Then, after reading the descriptive text, they might in all subsequent exposures understand and remember the symbol's meaning. Moreover, the accompanying words provide additional, more specific information that otherwise would be very difficult to convey by pictorial symbols alone. Of course, adding text will not directly help those lacking the skill to read it. Research also shows that relative to younger adults, older adults seem to prefer and are possibly more adept with textual instructions than symbolic instructions, possibly because of age-related differences in familiarity with the two kinds of media (Morrell *et al.*, 1990; Morrow, Leirer, and Andrassy, 1996; Sojourner and Wogalter, 1997, 1998).

8.4.10 Review of Pictorial Symbol Comprehension

In the preceding sections, general symbol-design principles based on research and guidelines were presented. While symbols can be helpful in communicating hazard-related information, symbols for many concepts may fail to produce high levels of comprehension, particularly for concepts that are complex or not easily visualized. Even without high levels of comprehension, pictorials may be useful components of warnings because of their ability to attract attention, to reinforce an accompanying verbal message, and to cue knowledge in memory. One must, however, purposely look for and avoid critical confusions.

8.5 UNDERSTANDING AUDITORY WARNINGS

In this section, we discuss factors that relate to the understanding and memory of auditory warnings. Chapter 7 by Wogalter and Leonard described various characteristics of sound-based warnings that affect attention capture and maintenance. Like visual warnings, auditory warnings can carry information and affect people's hazard comprehension.

8.5.1 Nonverbal Sounds

Simple auditory warnings (e.g., common tones and beeps) usually carry less information than complex sounds. Simple auditory warnings announce the fact that there is a problem but provide little additional information. Other more complex nonverbal auditory warnings can signal (or code) specific hazards by using different frequencies or temporal arrangements of sounds. However, for different sounds to be effective in signaling specific hazards, the receiver must be able to associate specific sounds with their meanings. Research indicates that only a limited number of nonverbal auditory signals should be used in any one system; having too many will make them difficult to discriminate, learn, and remember (Cooper, 1977; Banks and Boone, 1981). Even after the set is learned, retraining and practice may be necessary to ensure the signals' meanings are not forgotten (Patterson and Milroy, 1980).

Research indicates that the design and selection of nonverbal auditory sounds be based on existing stereotypical knowledge in the target population or, in other words, having high association value with the referent (Edworthy, Loxley, and Dennis, 1991; Hellier, Edworthy, and Dennis, 1993; Edworthy, Hellier, and Hards, 1995; Haas and Casali, 1995). For example, if one wanted a sound that would give information to an operator about the slowing down or the speeding up of some industrial process, one might use an auditory signal that modulates in accord with the speed of the machine. In this case, the sound might be of a higher pitch or with a quicker beat rate when the system is operating on 'high' and a lower pitch or a slower beat rate when the system is operating on 'low.' When the system is not working perfectly the sounds could be distorted to reflect the degree of machine malfunction. In other words, nonverbal sounds can be designed to reflect the state of the system, making them useful information displays. To avoid the need for extensive training to learn associations between an arbitrary set of auditory codes and their referents, it is wise to use what people already know as a partial basis for selection and design of sound cues.

8.5.2 Voice

Complex auditory messages also can be transmitted via voice (speech). Unlike complex nonverbal messages that require specific training to know the various meanings of the coded sounds, the use of speech makes available an extensive repertoire of pre-existing language skills that can be used to decode the meaning of the sound-based information. Thus, the number of different voice messages that can be conveyed without extensive training is considerably larger than that for nonverbal auditory signals.

Some messages are not conveyed as readily auditorily as they are visually because of the nature of the two senses. With voice presentation, the message is presented across time and one's ability to review earlier-presented material is limited without a mechanism for playback. Generally with visually presented material, the section can be reread if it is not understood the first time. Difficult material requiring complex surface-to-deep structure transformations tends to tie up large amounts of working memory capacity, and tends to be less well understood when presented by voice than by print (Penney, 1989). At the same time, if the warning message is short and relatively simple, presentation by voice can be very effective at capturing attention, making it more likely that the information will be conveyed and processed further. Indeed, research shows that short voice warnings can be more effective in producing behavioral compliance than the same message in print (Wogalter and Young, 1991; Wogalter, Kalsher, and Racicot, 1993).

Voice warnings are now commonly conveyed in mass-media broadcasts and in automated cockpit systems. Technological advances have made available inexpensive miniaturized digital recording and playback devices (as in phone answering machines and in some greeting cards). These inexpensive systems combined with detection devices (e.g., photoelectric and motion sensors) may be used in a variety of applications not previously considered practical. We expect that auditory-warning systems will become more sophisticated in the future, particularly in the area of selective presentation to avoid annoyance and habituation (see also Chapter 7 by Wogalter and Leonard).

8.6 COMPREHENSION TESTING

In the previous sections, we described factors that can improve comprehension. However, none of the preceding methods is definitive because they will not necessarily produce the best warnings. The process of developing warnings should not stop after applying a set of guidelines. Guidelines are useful in helping to form an initial set of designs or prototypes that then should be put through formal comprehension testing to assure that the warnings are understood as intended (i.e., whether they activate or produce the necessary information in memory).

Direct measurement of comprehension is the ultimate determinant of whether persons are properly informed about the hazard. As we noted earlier, compromises have to be made when following warnings guidelines (e.g., between brevity and explicitness). However, one does not know before testing is carried out whether the right tradeoffs have been made. The only way to know is to test it. Testing can determine whether comprehension is adequate and whether there is a need for more design improvements. Testing can also be used to gather feedback on potential design improvements.

Another reason for comprehension testing is that sometimes warnings designers and domain experts can misrecognize that they know what the target population knows, and that their particular experiences and beliefs may not be adequate to produce understandable warnings for the general public. Frantz, Miller, and Main (1993) investigated the ability of two different groups, engineering students and law students (potential designers of warnings) to estimate the effectiveness of a set of warnings that had already been measured in previous research. Less than half of them selected the most effective warnings.

In this chapter we do not describe the specific procedures involved in testing warning comprehension. Chapter 3 by Young and Lovvoll describes some of these methods in more detail. Also, the appendix of the most recent version of the ANSI (1998) Z535.3 safety symbol standard includes some suggested methods for testing symbol understandability. Although the Z535 standard does not describe explicitly how to test text messages, the test procedures can be adapted readily from the symbol testing methods (Wolff and Wogalter, 1998).

8.6.1 Participants

Obtaining an appropriate set of participants for comprehension testing can be difficult and time consuming. Frequently, college students are used because they are convenient to university-based researchers. A possible problem with student participants is that their knowledge and education may differ from the warning's target audience. Note though, that college students are not always inappropriate research participants for warning research; sometimes they are the target audience of concern, e.g., for warnings associated with alcoholic beverage consumption. In other situations, students can give a general indication how a different group of persons might perform (e.g., Leonard and Cummings, 1994; Magurno *et al.*, 1994). That is, if college students have difficulty understanding a warning, then surely less educated people will do no better. However, if college students perform very well, we will not know how the general public will respond. Fortunately, comparisons between the data of college students and other groups (e.g., participants solicited at flea markets) frequently show the same basic pattern of results, although college students generally produce more consistent (less variable) and sometimes higher scores than ordinary citizens (e.g., LaRue and Cohen, 1987; Silver *et al.*, 1991; Wogalter, Kalsher, Frederick, Magurno, and Brewster, 1998). Nevertheless, despite the concordance, a warning that will be used in actual applications should be tested using an appropriate sample of the target audience when possible (Laughery and Brelsford, 1991; Young, Laughery, Wogalter, and Lovvoll, 1998).

When a representative sample of the target audience cannot be obtained because of economic, technical, or logistical reasons, testing should focus on using a sample of persons at the lower end of the distribution of language skills, education, and socioeconomic status of the target population. Note that the data gathering process should not be directed at 'average' users because this would omit the most critical persons in terms of those who might not understand the material. Thus, if the warning is to appear on a consumer product (making the public at large the target audience), and if a fully representative sample of target users can not be secured, one should at least employ a sample including persons who have limited reading and language skills. Adult literacy programs and English as a second language programs (ESL) are good sources of such persons. Flea markets and community centers may be good sources of participants possessing a range of language skills and demographic characteristics.

8.6.2 Focus Groups

Another method of getting feedback on warning designs is focus groups. Groups of participants fitting some specific (usually demographic) criteria are brought together to discuss, with the aid of a facilitator, a set of issues that are considered relevant to the content and format of the warning being evaluated. The focus group participants must be given adequate background information about the hazard as well as potential injury scenarios. They are then encouraged to express their ideas and opinions and pros and cons about potential warning designs. However, the basic focus group method alone is inadequate for assessing comprehension. Some of its deficiencies include: (a) the use of small sample sizes; (b) the fact that one or two individuals may drive the entire group's ideas—thereby making the sample smaller than its nominal count; (c) these one or two individuals informing others in the group about hazards that they would not have recognized; and (d) only opinions are collected not actual knowledge or behavior. The primary problem stemming from these issues is that the best warning, one that informs and produces superior levels of safe behavior, may not be derived from the focus group method. Like the other methods discussed earlier, focus groups can be beneficial in the process of developing initial prototype warnings that later could be included in a formal comprehension test.

8.6.3 Open ended versus Multiple Choice

Although it is quite common for multiple-choice tests to be used to assess knowledge, often they are inappropriate for testing warnings-related comprehension. The main reason is that it is very difficult to develop plausible sets of alternative answers for a multiple-choice test that assess comprehension fairly. Wolff and Wogalter (1998) have shown that multiple-choice tests can produce erroneous results. The best comprehension tests involve open-ended questions, in which people are simply presented with a prototype warning (or a component of warning) and are asked what they understand about it. Open-ended tests are more difficult to score than multiple-choice tests. Judges (graders/scorers) must subjectively assess whether or not the responses should be counted as correct, which can be difficult when participants' answers are ambiguous/unclear. A standard procedure is to have more than one judge score the comprehension responses to obtain a measure of inter-judge agreement (reliability). See Collins (Chapter 12; this volume). Wolff and Wogalter (1998) and ANSI (1998) for more discussion on these points.

8.6.4 Context

Unfortunately, many studies evaluate warnings comprehension in contexts that are different from the eventual real-world situations in which a warning (or warning component) will appear. Providing the appropriate contextual information during the comprehension test not only makes the test more realistic, but it can also enhance understanding by cuing related knowledge which, in turn, could yield higher test scores than without context. Without contextual cues, the test may yield low comprehension scores which, in turn, would indicate the need for additional, and frequently costly, redesign and testing procedures. The warning might have performed much better had participants known where it would be located. Also, without an explicit context, participants may supply their own implicit context which may or may not reflect the actual context in which the warning will appear. For example, in a test where no specific context is provided, a pictorial symbol depicting a boot may produce two or more interpretations depending on the context inferred, e.g., that safety shoes must be worn or that a shoe store or repair shop is present. However, had a context been provided (e.g., showing it with a photograph of a construction site or a marketplace), the number of incorrect responses would be reduced.

Therefore, supplying context during comprehension testing should facilitate the finding (and reduce the cost of finding) an adequately understandable warning (Wolff and Wogalter, 1998; Leonard and Karnes, 1998).

8.6.5 Potential Shortcuts

Sometimes the development of adequate warnings can require considerable work. First, a set of prototype warnings based on research results and guidelines is produced, then the most likely candidates are put through a comprehension test. If the testing shows that many persons in the target audience do not understand the hazard and its important ramifications, then the prototype(s) should be modified based on feedback from the earlier test participants, followed by another comprehension test with another sample of people. The process continues iteratively (design, test, redesign, test, redesign, test) until a satisfactory level of comprehension is reached (Wolff and Wogalter, 1993; Dewar and Arthur, 1999; Magurno *et al.*, 1994). Several shortcut methods for testing pictorial symbols are described by Zwaga (1989) and Brugger (1999). This work shows that subjective ratings of understandability correlate with comprehension scores. Further research on the factors that predict comprehension should reduce some of the work involved in testing. For further information on comprehension testing, see Chapter 3 by Young and Lovvoll.

8.7 TRAINING

It is excessively optimistic to assume that people will encode and integrate large numbers of warnings simply by seeing them when they appear on equipment, on a product label, or in a manual. People engage in different degrees of 'reading'. If everyone grasped all of the information that they 'read,' all students would get near-perfect scores on tests at school and people, in general, would be better informed. As we know, people vary in how much they read and how much they comprehend. To ensure that people learn safety-related information, training may be necessary. Many large companies use training to ensure that employees know specific safety skills and procedures. Sometimes training can be quite brief, and other times, months or years of training (apprenticeship or schooling) are required. Because critical, potentially hazardous events tend to occur infrequently, periodic retraining may be necessary. To determine whether the training is producing knowledge and skills, some sort of follow-up test is necessary.

The basic premise of training is that it will promote the use of appropriate knowledge and skills when they are needed or, in other words, the effects of training transfers to actual real-world tasks. Transfer from training to actual use conditions can be positive (facilitating subsequent performance) or negative (retarding subsequent performance). One example of positive transfer is represented in Figure 8.7. Most people have learned the general concept of the circle/slash prohibition symbol, perhaps from seeing it in various other symbols such as those for 'No dogs' or 'No bicycles,' etc. From this prior experience, people are likely to transfer the knowledge that the circle/slash means 'No' to other prohibitions such as 'No bobsled' or 'Do not touch' symbols—even though they might not have seen the exact symbols before.

A situation involving negative transfer occurs when information learned earlier makes it more difficult to learn new material later. Consider the symbols shown in Figure 8.8. Suppose that a person initially learned that a flame symbol means fires are permitted (as in the symbol on the left indicating 'campfires allowed in area'), and then later tries to

Figure 8.7 Example of positive transfer. Knowing the meaning of the prohibitive symbol (e.g., as in 'No Dogs' or 'No Bicycles') can transfer so that one understands the meaning of the prohibitive symbol in newly seen symbols (e.g., 'No Bobsled' or 'Do Not Touch').

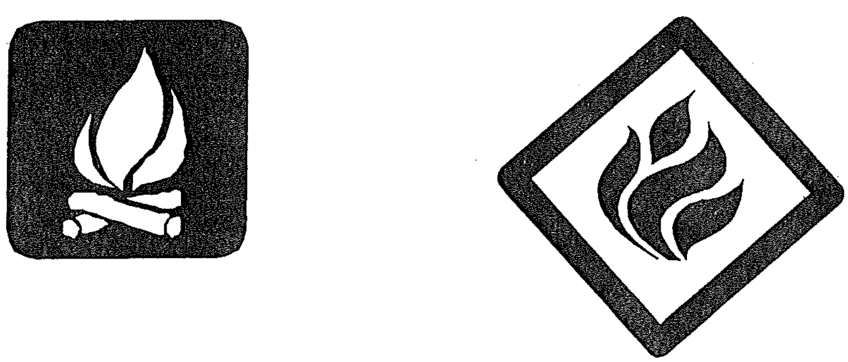

Figure 8.8 Example of negative transfer. Symbols for (a) campfires allowed in area, and (b) flammability—where fire is not permitted. Learning one symbol first can have negative transfer effects on learning a second similar symbol with a different meaning. In this particular example, there is the possibility of critical confusion.

learn that another flame symbol (on the right) indicates flammability ('fire is not permitted'). This second association to the flame symbol (flammability) might be more difficult to learn compared to one in which no earlier learned association had been formed to a symbol with a flame. Thus in negative transfer, prior learning interferes with learning a different association for a similar picture or concept.

The processes of encoding information into memory and its subsequent retrieval from memory are intimately linked. The particular encoding operations or study strategies used at the time of initial stimulus exposure determine whether and how well the information will be retrieved at a later time (Craik and Lockhart, 1972; Tulving and Thompson, 1973). In general, the best cues for retrieval are those that were present when the stimuli were encoded earlier. Thus to increase the likelihood of correct remembering, one should maximize the similarity between the conditions in which retrieval of the information is desirable and those that are employed during the study/training session.

Training can involve many methods. In the following sections, we describe three: (a) modeling, (b) simulation, and (c) paired-associate learning.

8.7.1 Modeling

Modeling involves exposing individuals to another person who demonstrates how to perform the pertinent tasks correctly and safely. The desired outcome is that the persons exposed to the model will reproduce the model's behavior. Research shows that modeling increases warning compliance after participants see a videotape presentation or a live model carrying out the proper safety procedures (Wogalter, Allison, and McKenna, 1989; Racicot and Wogalter, 1995). There are a wide variety of safety training video tapes currently available from assorted vendors. Frequently these videos employ modeling, but their effectiveness is largely unknown.

8.7.2 Simulation

A second training method, simulation, provides the opportunity to practice critical procedures under (safe) conditions that mimic actual conditions. During practice sessions, feedback is given for improving performance. For example, pilots practice in realistic cockpit simulators similar to the aircraft they will fly. A focus of this training is to put the pilots through a series of potential emergency scenarios under controlled conditions. Because emergency events occur infrequently, the proper skills might not otherwise be learned. Simulation provides the opportunity to learn and practice emergency procedures and responses. In addition, airline pilots undergo periodic refresher courses to ensure that they will not forget what to do when certain incidents and warnings are presented. Simulation is used also for training various other kinds of safety critical work including nuclear power plant operators responding to a potential accident, lifeguards practicing rescues, and nurses administering medications, among others.

8.7.3 Paired-associate Learning

Paired-associate learning has a long and extensive research history in the psychology literature. Numerous studies (see e.g., Deese and Hulse, 1967; Ashcraft, 1989) have documented the parameters of such training. Typically, pairs of stimulus items are

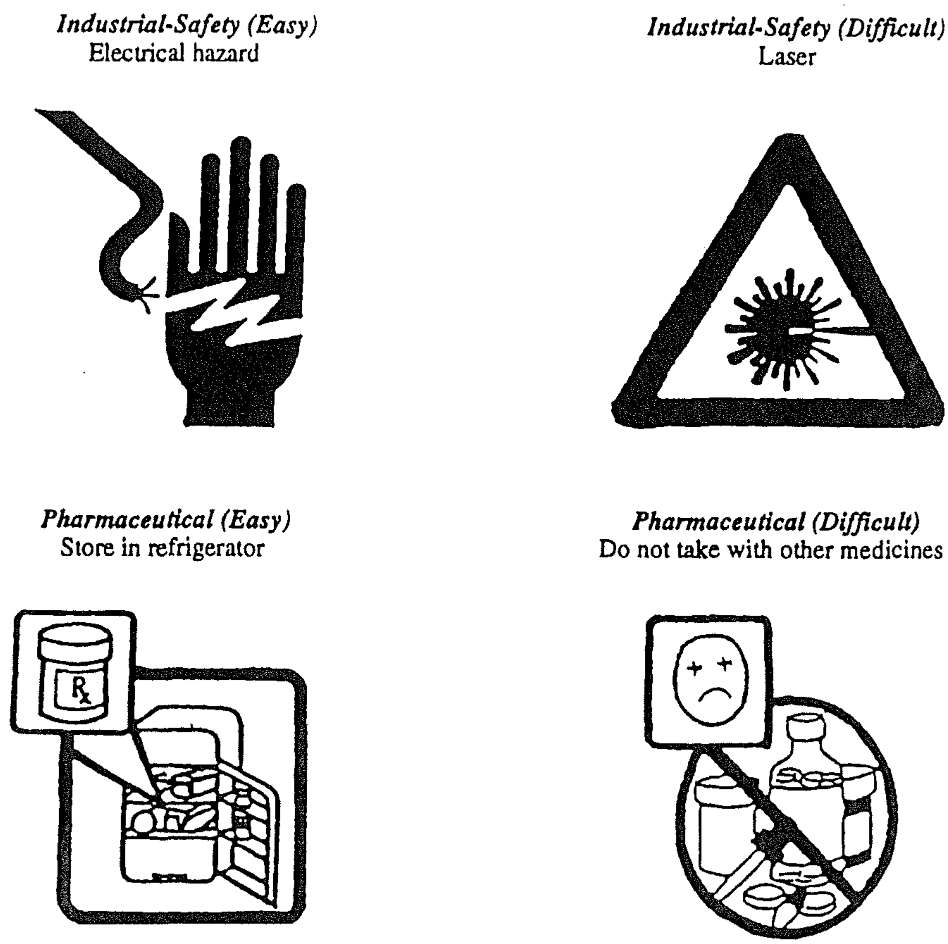

Figure 8.9 Easy and difficult pictorial symbols used in Wogalter *et al.* (1997b).

studied together, and later when one of the two is shown, memory is activated allowing information about the other stimulus to be retrieved. One application of this process is in learning the meaning of abstract symbols such as for biohazard and radiation. Wogalter, Sojourner, and Brelsford (1997b) have demonstrated the utility of paired-associate learning for symbol comprehension. They examined the effects of training on the comprehension of 'easy' and 'difficult' industrial-safety and pharmaceutical symbols in a pre- and post-test paradigm. The easy/difficult distinction was based on earlier comprehension test performance. As Table 8.2 shows, the easy items were comprehended well in the pretest, although not all of them reached the ANSI (1991, 1998) 85% correct comprehension criterion. The difficult items produced much poorer comprehension scores on the pre-test. Following a single trial of paired-associate presentation, both types of pictorial were understood at higher levels. The increase was particularly dramatic for the more difficult symbols, about 40% better after a single training trial. These gains were maintained over time, as shown by a delayed post-test administered to another group of participants one week after training. A smaller-scale follow-up study showed only a small drop in performance six months later.

Table 8.2 Proportion correct as a function of easy versus difficult pharmaceutical and industrial safety symbols before training, immediately following training, or 7–10 days following training (adapted from Wogalter *et al.*, 1997b).

	Pharmaceutical		Industrial	
	Easy	Difficult	Easy	Difficult
Initial test (before training)	.89	.47	.68	.33
Immediate post-training test	.96	.85	.89	.78
Delayed test (7–10 days later)	.97	.82	.90	.72

8.8 HAZARD IMPRESSION

Most of this chapter has dealt with attaining or activating knowledge for specific hazard-related concepts, including the meaning of text and pictorial symbols. In this section, we describe a different kind of information processing. This processing is *less* content-specific and more general, and it concerns the overall impression formed from a warning. The impression produced is a general feeling of danger (dangerousness)—that something bad is possible. In the warnings research literature, this dimension has been given various labels such as perceived hazardousness, arousal strength, and urgency. This impression can be formed regardless of whether the individual understands the specific content of the warning message.

The production of an appropriate hazard impression can reduce some of the problems cited earlier regarding comprehension difficulties experienced by persons who, for example, have lower-level language skills, but will not eliminate the problem entirely. Hazard impression can be helpful to individuals who fail to understand parts of the warning, either because of their personal limitations or when suboptimal conditions exist. If one or more cues of a multi-feature warning cannot be seen or interpreted accurately, then the remaining cues might compensate by providing an overall hazard impression. Also, the formation of an overall impression can serve as a redundant cue along with the specific message content of the text or symbols. We discuss other cues in the sections that follow.

8.8.1 Color

Certain colors such as red, orange, and yellow are used commonly to indicate different levels of hazard (from greater to lesser, respectively) (Bresnahan and Bryk, 1975; Westinghouse Electric Corporation, 1981; Collins, 1983; FMC Corporation, 1985; ANSI, 1991, 1998; Chapanis, 1994). Research has consistently shown that people in western cultures understand that red connotes hazard (Braun and Silver, 1995; Griffith, 1995; Wogalter *et al.*, 1997a, 1998). Two other colors, orange and yellow, connote lower hazard than red, but people do not readily differentiate between the two on the perceived hazard dimension (Chapanis, 1994; Griffith, 1995; Wogalter *et al.*, 1998). Besides the above-mentioned three colors and black, most of the other common colors connote little or no hazard.

8.8.2 Surrounding Shape

Sometimes warnings are enclosed in differently-shaped surround borders. The conventional 'STOP' sign is recognizable by its octagon shape. Through past experience we have learned an association among the features that comprise its octagon shape, its color red, and the word STOP. The triangular yield sign is perhaps almost as well recognized. Riley, Cochran, and Ballard (1982) examined 19 different symbol shapes with regard to hazard association. The shape most associated with hazard was the triangle (particularly with one point aimed downward). Also highly rated were a diamond, an octagon, a hexagon, and a pentagon; rounded shapes received lower ratings.

While people may understand the above-mentioned shapes, surround shape probably serves a minor role in hazard impressions relative to other potential cues. Because surround shapes do not carry much meaning in and of themselves, some sort of training or experience is required for people to recognize the intended meanings. Another problem is that surround shapes are used inconsistently across warning systems (Dewar, 1999).

On a related matter, research (Wogalter, Laughery, and Barfield, 1997c) suggests that some container shapes (e.g., the outline shape of a paint can or of an industrial-type barrel) connote greater hazard than other container shapes (e.g., the outline shape of a soda bottle or of a milk carton). This result suggests that in addition to what the label looks like and says, the container shape can provide a cue about how hazardous the substance is inside.

Also, research shows that physical characteristics of different designs of rectangular borders around a warning can influence hazard perceptions. Participants rated 51 borders that differed in color, width, and design on the dimensions of attention-capture, willingness to read the warning, and perceived hazard on 9 point scales (0 = 'not at all' to 8 = 'extremely' on the dimension). **Figure 8.10 (see color section)** shows some of the border stimuli examined by Rashid and Wogalter (1997). Tables 8.3 and 8.4 show summary statistics of the resulting hazard ratings. The tables show that the thicker borders with a red solid border or with black and red or yellow diagonal stripes produced the highest perceived hazard ratings. In a follow-up study, Wogalter and Rashid (1998) showed that the borders that received high ratings in the earlier study also were more likely to be looked at when on a sign posted in a public area.

8.8.3 Internal Shapes

Sometimes certain kinds of geometrical/configural information are included within the warning. The ANSI (1991) Z535.2 standard for environmental warning signs includes shape configurations as part of the topmost header panel containing the signal word. For example, the signal word DANGER is enclosed in an oval shape and WARNING is enclosed within an elongated hexagon shape. Some of these shape components do not carry much hazard association value by themselves (Wogalter *et al.*, 1998). Jaynes and Boles (1990) used some of Riley *et al.*'s (1982) shapes and showed no effect on behavioral compliance rates. Other research has shown that diagonal stripes, the signal icon (the alert symbol with a triangle enclosing an exclamation point), and a simple skull symbol are perceived to indicate moderate to high levels of hazardousness (Wogalter *et al.*, 1998).

Table 8.3 Mean ratings of attention capture, willingness to read warning, and perceived hazard for 51 borders comprised of combinations of color, width, and design configuration (from Rashid and Wogalter, 1997).[a]

Configuration	Width	Attention	Read	Hazard	Configuration	Width	Attention	Read	Hazard
No border	NA	0.50	1.33	NA	Black line	I	1.38	2.21	2.83
Yellow line	I	1.54	2.33	2.21	Black parallel lines	III	1.71	2.92	2.63
Yellow parallel lines	III	1.92	2.71	2.54	Green line	I	2.08	2.38	2.71
Blue line	I	2.29	2.54	2.13	Green parallel lines	III	2.42	2.83	2.54
Black line	II	2.58	3.33	3.33	Red line	I	2.58	3.13	3.50
Blue parallel lines	III	2.63	2.79	2.46	Red parallel lines	III	2.96	3.88	4.38
Black line	III	3.04	3.83	4.04	Blue line	II	3.08	3.42	3.08
Black jagged line	III	3.08	3.75	4.13	Yellow jagged line	III	3.08	3.13	3.67
Black/white stripes	II	3.08	3.83	4.00	Green line	II	3.17	3.50	3.25
Black 7 lines	III	3.25	3.33	3.54	Yellow line	II	3.33	3.79	3.63
Black/white stripes	III	3.58	4.25	5.04	Blue line	III	3.58	4.42	2.92
Blue 7 lines	III	3.58	3.88	3.21	Green jagged line	III	3.71	4.13	4.21
Yellow 7 lines	III	3.75	3.75	3.25	Black inward arrows	III	3.83	4.75	3.96
Blue jagged line	III	4.00	4.33	3.79	Green line	III	4.08	4.38	4.13
Red line	II	4.13	4.88	5.42	Yellow saw-tooth	III	4.17	4.08	4.83
Yellow line	III	4.20	4.46	4.13	Black saw-tooth	III	4.21	4.58	4.58
Green 7 lines	III	4.21	4.42	3.25	Black/green stripes	II	4.38	4.46	4.88
Black and blue stripes	II	4.46	4.46	4.38	Blue saw-tooth	III	4.46	5.17	4.67
Red 7 lines	III	4.58	5.13	5.54	Red jagged line	III	4.75	4.83	5.79
Black/red stripes	II	4.75	5.42	6.50	Black/blue stripes	III	4.92	5.29	4.71
Black/green stripes	III	5.04	5.50	5.17	Green inward arrows	III	5.08	5.13	4.54
Red line	III	5.13	6.04	6.13	Green saw-tooth	III	5.50	5.21	5.38
Yellow inward arrows	III	5.58	5.86	5.04	Blue inward arrows	III	5.58	5.13	4.25
Black/yellow stripes	II	5.63	5.63	5.88	Red inward arrows	III	5.83	5.83	6.00
Red saw-tooth	III	6.04	6.33	6.63	Black/red stripes	III	6.08	6.17	6.58
Black/yellow stripes	III	6.25	6.71	6.71					

[a] Note: border widths: I = 0.07 cm; II = 0.35 cm; and III = 0.71 cm; NA = not applicable.
Ratings were based on Likert-type scales anchored at end points with (0) 'not at all' and (8) 'extremely.'

Table 8.4 Mean ratings of attention capture, willingness to read warning, and perceived hazard for borders differing in color, width, and design configuration in which data are collapsed across conditions (from Rashid and Wogalter, 1997).[a]

Configuration	Attention	Read	Hazard	Configuration	Width	Attention	Read	Hazard
COLOR				*WIDTH and DESIGN*				
Red	4.68	5.16	5.64	No border	NA	0.50	1.33	NA
Yellow	3.95	4.25	4.19	single line	I	2.52	1.98	2.67
Green	3.97	4.19	4.00	single line	II	3.78	3.26	3.74
Blue	3.86	4.14	3.56	single line	III	4.62	4.01	4.27
Black	2.97	3.68	3.81	Parallel lines	III	3.03	2.32	2.90
				Seven lines	III	4.10	3.88	3.78
				Jagged lines	III	4.03	3.72	4.32
				Saw-tooth	III	5.01	4.88	5.22
				Inward arrows	III	5.34	5.18	4.76
				Colored stripes	II	4.46	4.76	5.13
				Colored stripes	III	5.58	5.12	5.64

[a] Note: I = 0.07 cm; II = 0.35 cm; and III = 0.71 cm widths; NA = not applicable.
Ratings were based on Likert-type scales anchored at end points with (0) 'not at all' and (8) 'extremely'.

8.8.4 Pictorial Symbols

Pictorial symbols differ from the other shapes that we have discussed in that they tend to be more detailed. We have already discussed the contribution of pictorial symbols to warning noticeability (Chapter 7 by Wogalter and Leonard) and comprehension (earlier in this chapter). In addition, symbols may convey or produce a hazard impression. This function would be important for difficult-to-depict concepts (e.g., those that are less visible, abstract, and highly technical) that people might not understand without accompanying verbal material or training. Consider the two cancer symbols in Figure 8.11. The one on the right seems to give a greater sense of hazard. A person who has never learned an association between the referent and its symbol might grasp the general gist of danger (hazard impression) just by looking at this form (though the person may not know that 'C' indicates cancer).

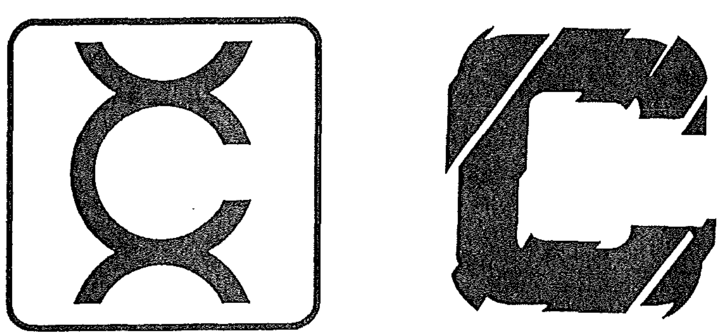

Figure 8.11 Two cancer symbols. Both are abstract but the one on the right gives a greater impression of hazard than the one on the left.

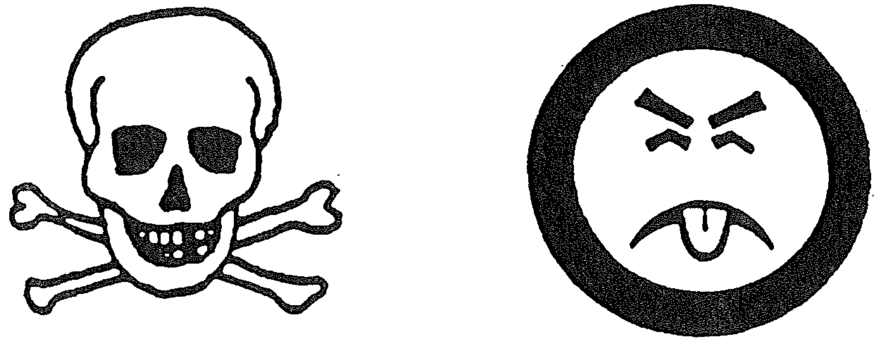

Figure 8.12 The skull and crossbones symbol and the Mr. Yuk symbol. Permission to reprint Mr. Yuk symbol granted by Children's Hospital of Pittsburgh.

Casey (1993) presents an interesting story about a grain shipment sent to Kurd villages in northern Iraq that was specifically meant for planting as a crop (not for direct consumption). The seeds were dyed red to indicate that they were not safe for eating. That year there was a major drought and the land remained parched and could not be seeded. This brought famine and starvation. Shortly afterwards, people began entering hospitals with severe neurological symptoms, such as inability to control their limbs. After considerable painstaking investigation, it was discovered that the neurological symptoms were due to mercury poisoning and this was subsequently tied to the grain which had been sprayed with a preservative that contained a form of mercury. The grain had been dyed to indicate that it was unfit for consumption. The on-site investigators discovered that all of the grain cases and bags prominently displayed the skull and crossbones symbol for poison (see left side of Figure 8.12). When the Kurd villagers were asked what this symbol meant, almost no one knew. They thought it was just another American design (perhaps a company logo) with no particular significance. They did wonder why the grain was red but it did not stop them from scrubbing it off with water (but unfortunately still leaving some mercury in the grain which later was made into foodstuffs and eaten). The point is that due to cultural differences not everyone understands what we might think would be one of our better danger-connoting symbols.

There's another interesting story related to the skull and crossbones symbol. The Mr. Yuk symbol shown on the right side of Figure 8.12 was developed as a substitute for the skull and crossbones symbol, because young children did not understand that the original skull and crossbones symbol indicated poison.

When designing a symbol, it may be possible to communicate the presence and level of a hazard by its inherent shape, even though individuals may not know the identity of the specific referent concept. It might be possible to redesign the biohazard and radiation symbols to enhance their perceived danger even to persons who do not know their specific meaning. It may be possible to do this by re-forming 'soft' curves within the existing symbols into 'sharp,' 'hard,' 'cutting' angles and making the appendages bolder/fatter (as opposed to thinner).

8.8.5 Signal Words

Warnings often contain specific words intended to alert people to the presence of a hazard and the level of danger involved (severity and probability). In the USA the ANSI (1991, 1998) Z535 standards recommend the specific terms DANGER, WARNING, and

Table 8.5 Mean carefulness ratings of signal words known by 95% or more of the fourth and fifth graders and by 80% or more of the non-native English speakers. Also shown are college student and elderly participant ratings (Wogalter and Silver, 1995).[a]

	Study 1		Study 2	
	4th and 5th graders	ASU college students	Elderly	Non-native English speakers
NOTICE	5.39	4.01	5.00	3.64
CAREFUL	5.86	4.76	5.23	5.88
ALARM	6.16	5.01	6.09	4.87
IMPORTANT	5.95	5.06	5.59	5.64
CAUTION	6.64	5.22	5.91	4.75
DON'T	6.12	5.24	5.93	4.54
NO	5.63	5.60	5.81	4.68
SERIOUS	6.90	5.73	6.43	5.52
NEVER	6.09	5.93	6.27	5.34
WARNING	6.52	6.13	6.49	5.58
HOT	6.00	6.21	6.61	4.40
STOP	6.11	6.43	6.95	6.55
DANGER	7.12	6.49	7.00	7.63
DANGEROUS	7.18	6.64	7.04	7.66
POISON	7.49	7.00	7.57	7.93

[a] Note: selection of terms based on missing-value indicators of understandability.

CAUTION to be used as signal words to connote high to low levels of hazard, respectively (see also FMC Corporation, 1985). DANGER is intended for immediate hazards that will result in severe personal injury or death; WARNING is intended for hazards that could result in severe personal injury or death; and CAUTION is intended for hazards which could result in minor personal injury or damage to apparatus (FMC Corporation, 1985). Because most people do not know the formally assigned definitions and cannot accurately assign the definitions to the words when they are provided (Drake, Conzola, and Wogalter, 1998), their effect is mainly to alert people to the presence of a hazard and to produce an overall impression of the level of hazard. While some studies have shown little or no difference between DANGER, WARNING or CAUTION (Ursic, 1984; Leonard, Mathews and Karnes, 1986; Wogalter *et al.*, 1987, 1998; Griffith, 1995), others have shown a fairly strong difference between DANGER compared to WARNING or CAUTION on perceived hazard (Bresnahan and Bryk, 1975; Dunlap, Granda, and Kustas, 1986; Leonard, Hill, and Karnes, 1989; Wogalter and Silver, 1990, 1995; Chapanis, 1994). Although sometimes statistically significant differences between WARNING and CAUTION are found, the mean differences usually are practically insignificant. Research has also investigated other potential signal words that may cover the range of the hazard dimension more effectively. One term, DEADLY, consistently produces greater levels of perceived hazard than the term DANGER (Leonard, Karnes, and Schneider, 1988; Wogalter and Silver, 1990, 1995). DEADLY could be used only for the most extreme hazards, and in this way avoid people discounting the seriousness associated with the ubiquitous DANGER signal word (Wogalter and Silver, 1990, 1995).

Table 8.5 shows a set of signal words that are understandable by 95% or more of young grade-school children (fourth and fifth graders) and by 80% or more of non-native

English readers. Also shown in this table are the ratings from college student and older adult participants (Wogalter and Silver, 1995). The words cover a much larger range of hazard than the three conventional ANSI terms, and probably they could be used as alternative terms to reduce habituation.

8.8.6 Multiple Features

The various features described can be used in combination to help cue hazards. The header panels recommended in ANSI Z535 combine multiple features, including a signal word, a colored surround, and a graphic (either the signal icon or a geometric shape). Wogalter *et al.* (1998) examined various individual components and combinations of components in header panels. Examples were shown in Chapter 7 by Wogalter and Leonard in **Figures 7.1 and 7.2 (see color section)**. Tables 8.6 and 8.7 show the mean hazard ratings. Probably the combined presence of multiple redundant features is most useful when seen under suboptimal conditions in which portions of the warning are not visible or not understood. The inclusion of multiple features provides alternative/redundant cues that one can hope will be adequate to provide the hazard information under suboptimal conditions.

8.8.7 Auditory Urgency

The idea of systematically matching (mapping) warning stimuli to actual hazards has been a major topic in the auditory warning literature. Edworthy and her colleagues (Edworthy and Adams, 1996; Edworthy *et al.*, 1995b) have described factors that influence the perceived urgency of nonverbal auditory warnings. Because hazards vary in degree, it makes sense that the sound itself (ignoring the content of the word) provides a sense of urgency consonant with actual hazard level. Research has shown that sounds having

Table 8.6 Mean hazard perception ratings (overall and by participant group) and standard deviations for overall ratings.

Set-#	Stimulus	Ratings			
		Overall		Undergrad.	Comm. Vol.
		Mean	SD	Mean	Mean
Set A	*Solid colors*				
A-31	Red	3.2	1.1	3.2	3.1
A-58	Yellow	2.2	1.1	2.2	2.2
A-25	Orange	2.0	1.1	2.0	1.9
A-68	Black	1.7	1.5	2.0	1.5
A-60	Purple	0.8	1.0	1.0	0.6
A-64	Green	0.8	1.0	1.1	0.4
A-70	Blue	0.7	0.9	0.8	0.6
A-46	White	0.6	0.9	1.0	0.2
Set B	*Multi colors*				
B-69	Black/yellow	2.3	1.4	2.3	2.2
B-37	Black/red/white	2.1	1.2	2.0	2.2

Table 8.6 *(cont'd)*

Set-#	Stimulus	Ratings			
		Overall		Undergrad.	Comm. Vol.
		Mean	SD	Mean	Mean
B-50	Red/white	2.1	1.2	1.9	2.2
B-49	Black/orange	2.0	1.1	2.0	1.9
B-79	Black/white/red	1.9	1.2	1.7	2.1
B-65	Black/white	1.4	1.2	1.2	1.6
Set C	*Shape and color configurations*				
C-34	White skull in black square	3.8	0.6	3.9	3.7
C-83	Red oval in black rectangle	2.6	1.1	2.4	2.8
C-80	Black/yellow diagonal stripes	2.6	1.0	2.6	2.6
C-47	White ! in black triangle	2.3	1.1	2.4	2.1
C-84	Orange elongated hexagon in Black rectangle	2.0	1.2	1.8	2.2
C-6	Black/white diagonal stripes	1.7	1.0	1.5	1.9
C-21	Black triangle	1.4	1.0	1.3	1.5
C-51	Black elongated hexagon in black rectangle	1.1	1.1	0.9	1.4
C-12	Black oval in black rectangle	1.1	1.1	0.8	1.4
C-81	Black capsule (lozenge shape) in black rectangle	1.0	1.1	0.7	1.4
C-23	Black square	1.0	1.0	0.8	1.1
C-55	Black circle	0.9	1.0	0.8	1.1
Set D	*Signal words*				
D-32	DEADLY	3.8	0.6	4.0	3.6
D-53	DANGER	3.4	0.6	3.4	3.5
D-76	WARNING	2.6	0.9	2.6	2.6
D-35	CAUTION	2.3	0.8	2.5	2.0
D-11	SAFETY FIRST	1.4	1.1	1.1	1.6
D-39	NOTICE	1.2	0.8	1.2	1.2
Set E	*Nonsense word headers*				
E-52	White print and skull on red background	3.7	0.6	3.9	3.6
E-13	White print and skull on black background	3.6	0.8	3.7	3.5
E-63	White print and triangle / ! on red background	2.7	1.1	3.0	2.5
E-48	White print in red oval on black background	2.5	0.9	2.3	2.6
E-22	White print and triangle / ! on yellow background	2.4	0.9	2.6	2.2
E-67	Black print in orange elongated hexagon on black background	2.1	1.0	2.0	2.2
E-44	Yellow print on black background	2.0	0.1	1.9	2.1

Table 8.7 Mean hazard ratings, within-set rankings, and noticeability ratings for ANSI Z535.2, ANSI Z535.4, and alternative formats.

Rating		Hazard rating			Hazard ranking	
#	Signal word	Overall	Undergrad.	Comm. Vol.	Overall	Noticeability
ANSI Z535.2 sign format						
24	DANGER	3.2	2.9	3.3	1.4	3.1
20	WARNING	2.7	2.5	2.7	2.4	2.7
66	CAUTION	2.4	2.5	2.4	2.4	2.8
71	NOTICE	1.2	1.2	1.2	4.2	1.4
56	SAFETY FIRST	1.1	1.4	1.0	4.6	1.4
ANSI Z535.4 product label format						
40	DANGER	3.4	3.1	3.5	1.1	3.4
62	WARNING	2.5	2.2	2.6	2.5	2.6
43	CAUTION	2.3	2.2	2.3	2.5	2.6
01	NOTICE	1.1	1.1	1.1	3.9	1.3
Proposed formats						
73	DANGER	3.1	2.8	3.2	4.0	3.1
04	WARNING	2.4	2.2	2.5	5.3	2.4
16	CAUTION	2.1	2.2	2.1	5.3	2.2
75	NOTICE	1.4	1.3	1.4	6.9	1.7
45	DEADLY	3.8	3.8	3.9	1.4	3.8
80	Deadly	3.7	3.7	3.7	2.0	3.6
38	DEADLY (reversed color)	3.6	3.3	3.6	3.1	3.3

certain characteristics (e.g., higher frequency/pitch, faster beat rate) connote greater urgency levels (Edworthy *et al.*, 1991, 1995a; Hellier *et al.*, 1993; Haas and Casali, 1995).

More recently, research has begun to investigate the effects of voicing style on signaling urgency/hazard. Signal words presented in an emotionally charged female voice connote greater hazardousness judgments than the same words presented in a monotone male voice (Barzegar and Wogalter, 1998a,b; Edworthy, Clift-Matthews, and Crowther, 1998).

8.9 FAMILIARITY AND HABITUATION

The old adage, 'familiarity breeds contempt,' has some truth. A substantial body of research shows that familiarity with a product is associated strongly with lower hazard perceptions and a reduced tendency to look for warnings (e.g., Wright, Creighton, and Threlfall, 1982; Godfrey, Allender, Laughery, and Smith, 1983; Godfrey and Laughery, 1984; Leonard and Hill, 1989; Wogalter, Brelsford, Desaulniers, and Laughery, 1991). A problem related to familiarity is habituation. Habituation refers to the tendency for individuals to ignore stimuli after repeated exposure to the same stimulus (see also Chapter 2 by Wogalter, DeJoy, and Laughery, and Chapter 7 by Wogalter and Leonard). The occurrence of habituation indicates that at least some of the stimulus information is in memory.

Unfortunately, this memory may be a fraction of the total content of a warning. In other words, people might stop noticing and looking at a warning before they know all of its content. Ideally, one would like to present reliably a warning only at the times necessary to prevent unsafe behavior that would otherwise occur. However, in practice this is not possible and, consequently, warnings will be seen and heard when no unsafe behavior would potentially occur. Nevertheless, to decrease habituation one might want to alter or change warning stimuli to capture attention, like variable-information signs currently found on some major urban highways. To be on the safe side one would still probably want to present warnings more often than not, even if there is some possibility of habituation. On some non-durable consumer products purchased on a fairly consistent basis (e.g., cigarettes, beverage alcohol), a rotating-type presentation method could be used (Wogalter and Brelsford, 1994). Varying the look and the content of the warning will help to counteract habituation as well as increase knowledge (e.g., von Restorff, 1933; Wogalter and Brelsford, 1994).

8.10 PROSPECTIVE MEMORY

Most of the cognitive processes discussed thus far have dealt mainly with retrieval of items or events from the past. This is called retrospective memory, and involves recall of events that have already occurred. Prospective memory refers to remembering in advance of performing some task or, in other words, remembering to do an activity at some appropriate time in the future (Einstein and McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, and Cunfer, 1995). One plans at time A to carry out a task at time B and, if successful, one actually does remember to do the task at time B. One example is a worker remembering at the necessary time to lock-out or tag-out industrial equipment before commencing maintenance or repairs (so that the machine is not accidentally started). In using medicines one needs to remember when to take the medication and/or the specific conditions for its consumption (e.g., instructions to take twice a day an hour after eating dairy and calcium-containing products, or two hours before drinking alcohol). Automatic timers with auditory signals are available to aid prospective memory. Prospective memory can be aided also by content of the warning material. Suppose an individual wished to spray a flammable pesticide in a living-room area. The printed label instructions might state to cover furniture and other objects, followed by a directive to extinguish any pilot lights. Can the individual remember to turn off the pilot light after covering all of the furniture? Clearly, any damage to the furniture is less important than an explosion. Because prospective memory, like other types of memory, can fail, the warning instructions should direct users to turn off the pilot lights first. Prospective memory is particularly important when the compliance behavior is to be performed some time after warning exposure. Like other types of memory, it helps to have a cue (a reminder) at the time the compliance behavior needs to be performed. This relatively new area of research is likely to provide more knowledge on how to facilitate retrieval at the appropriate time in the future.

8.11 SUMMARY AND RECOMMENDATIONS

A number of warning guidelines can be put forward from this review of comprehension and memory factors. To facilitate warning comprehension, the designer should:

- Use simple language
- Verify that the text and symbols convey the intended meaning to the target population at risk
- Describe carefully and explicitly the nature of the hazard, the instructions on how to avoid the hazard, and the consequences of failing to avoid the hazard
- Design prototypes based on existing research and guidelines
- Test the best prototypes with at-risk individuals who may be least knowledgeable about the hazard
- Redesign a warning when testing reveals the target audience does not acquire the message intended.

To make warnings more memorable, one should:

- Use textual and pictorial materials that are meaningful and organized
- Provide cues to assist retrieval
- Provide training when considerable amounts of hazard-related information need to be learned
- Change the warnings occasionally so that the effects of habituation are reduced.

People should not be expected to expend substantial amounts of effort to understand warning messages. If the process is effortful, people are less likely to encode the material in the first place, but even if they do they may stop encoding the information before processing all of it. In short, warnings should be designed to convey safety messages quickly and adequately.

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