

CHAPTER 32

WARNINGS AND HAZARD COMMUNICATIONS

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1 INTRODUCTION

Safety communications, such as warnings, are used to inform people about hazards and to provide instructions so as to avoid or minimize undesirable consequences. Warnings may be used to address environmental hazards as well as hazards associated with the use of products. In the United States, interest in warnings is also related to litigation concerns. The adequacy of warnings has become a prevalent issue in product liability and personal injury litigation. According to the Restatement of Torts (second) and to the Theory of Strict Liability, if a product needs a warning and it is absent or defective, the product is defective (see Madden, 1999).

Regulations, standards, and guidelines as to when and how to warn have been developed more extensively in the last three decades. Also, there has been a substantial increase in research activity on the topic during this time. Human factors specialists, or ergonomists, have played a major role in the research and the technical literature that has resulted.

In this chapter we review some of the major concepts and findings regarding factors that influence warning effectiveness. Most of the review is presented in the context of a communication–human information processing (C-HIP) model. The model is not only useful for organizing research findings, but it also provides a predictive and investigative tool. Following the presentation of the model and the review of major concepts and findings, a number of suggestions and recommendations for designing warnings is presented.

1.1 Hazard Control Hierarchy

In the United States and many other parts of the world, product manufacturers are responsible for providing safe products. To meet this responsibility, they should undertake a hazard analysis (e.g., fault tree, failure modes, critical incident) and examine pertinent databases to determine what hazards the product may pose in foreseeable use and misuse. Once hazards are identified, the next step is to determine how the hazards can be controlled. It should be recognized that warnings are usually not the first choice for controlling hazards and promoting safety. Rather, it is one tool that designers and manufacturers may use. Compared to other methods for protecting people and property, warnings have relatively limited reliability. Even the best warnings are not always 100% reliable or effective. The classic *hazard control hierarchy*, or a variant of it, is frequently a part of the analysis (Sanders and McCormick, 1993). This hierarchy defines a sequence of approaches in order of preference for dealing with hazards. The basic sequence is first to design the hazard out, second to guard, and third to warn. The first preference, the notion of eliminating the hazard through alternative design, is generally the best. If a type of poison can be removed from a product (e.g., lead in paint) and a safer substitute used, then the reformulation should be adopted. Beveling a sharp edge would eliminate or lessen a cutting hazard, and so on. Frequently, it is not possible to eliminate all hazards and still have the product function as intended.

The second line of defense is guarding; its purpose is to prevent contact between people and the hazard. There are several forms of guarding. Personal protective equipment, road barricades, and a lock on an electrical box are examples of physical barriers. Designing tasks in such a way to keep people away from a hazard is an example of a procedural guard. The "dead-man" switch on a lawn mower that shuts off the rotor when the handle is released is one such example, and requiring a physician's prescription to buy certain drugs is another. However, guarding, like hazard elimination, is not always a feasible solution.

The third line of defense is to warn. Warnings are the third priority in this sequence because, as mentioned above, they are not always reliable. Depending on the circumstances, the person at risk may not see or hear a warning, may not understand it, may not believe it, or may not be motivated to comply. Influencing behavior is sometimes difficult, and seldom foolproof. An implication of the hazard-control priority sequence is that warnings are not a substitute for good design or guarding. Indeed, where appropriate, warnings should be viewed as a supplement, not a substitute, to the other approaches to safety (Lehto and Salvendy, 1995).

In addition to the three-part hierarchy, other approaches may be effective in dealing with hazards. Generally, they fall into the same category as warnings in that they mostly involve communications that are intended to influence behavior. Training and personnel selection are examples. Another approach that includes elements similar to procedural guarding and warnings is supervisory control. These three approaches are applicable primarily to hazards in work environments.

1.2 Purposes of Warnings

Warnings have several purposes. First, warnings are a method for communicating important safety or safety-related information to a target audience who can then make better, more informed decisions regarding safety issues. Second, warnings are ultimately intended to reduce or prevent health problems, workplace accidents, personal injury, and property damage. To accomplish this, warnings are intended to influence or modify people's behavior in ways that will improve safety. Third, warnings may serve as a reminder, to call into awareness the hazard that may otherwise be latent in long-term memory.

There are two additional points to be noted regarding the purpose of warnings. First, warnings are a means of shifting or assigning responsibility for safety to people in the system (e.g., the product user, the worker) in situations where hazards cannot be designed out or guarded adequately. This is not to say that people do not have safety responsibilities independent of warnings; of course they do. Rather, a purpose of warnings is to provide the information necessary to enable them to carry out such responsibilities. The second point concerns people's right to know. The notion is that even in situations where the likelihood of warnings being effective may not be high, people have the right to be informed about safety problems confronting

them. Obviously, this aspect of warnings is more of a personal, societal, and legal concern than a human factors issue, and although it is not addressed further in this chapter, it is a matter that is related to the overall purposes of warnings.

2 WHAT, WHO, WHEN, AND WHERE TO WARN

What to Warn Warnings are a form of safety communications. There are many kinds of warnings. Warnings can be in the form of signs, labels, product inserts and manuals, tags, audio and video tapes, face-to-face verbal statements, and so on. Printed warnings are generally text and graphics. Auditory warnings may be verbal and/or nonverbal. In this chapter we describe factors that are generally applicable to all types of warnings, although the examples given are geared mostly toward visual warnings associated with products. There are three kinds or categories of information to be included in warning-message text: hazard information, consequences information, and instructions. Each of these categories is addressed in subsequent sections.

Who to Warn Persons at risk are to be warned. The general principle regarding who should be warned is that it should include everyone who may be exposed to the hazard (who are at risk) and everyone who may be able to do something about it.

Warnings may be directed to a very specific audience. For example, warnings about toxic shock syndrome from the use of tampons would be directed primarily to women of childbearing age. On the other hand, warnings may be intended for the general public, such as an electric shock warning on the consumer appliances.

Although warnings are usually directed at end users, they may also be directed at intermediaries such as physicians who prescribe medications and job supervisors who make decisions about workplace safety. Who is to be warned is obviously a factor in the design of warnings used. Warnings for surgical equipment such as a laser scalpel can be written at higher levels of technical verbiage, because it can be assumed that users have had education and training to understand the language. This point relates to the concept of learned intermediary, which is frequently used in medical communications about prescription drugs. The warnings directed to physicians can be much more complex than would be appropriate for end users (patients), because physicians have had extensive training relevant to the use of drugs by their patients. This notion carries with it the assumption that end users may be less capable of understanding at least some of the warning material. A similar situation is communicating warnings about products that are hazardous to children. Here the learned intermediary is the caretaker.

Consumer products, however, are generally intended for a much wider group of people, sometimes the entire population. In such cases, the warning designer must be sensitive to the capabilities of a

wide range of users. A general principle in warnings is that they should be written to take into account the lowest level of abilities training and experience in the target population. Some persons are color blind. Therefore, color should not be the only indicative cue for a hazard; there should be other cues (i.e., have redundancy). Some persons, such as older adults, have visual decrements (e.g., presbyopia), which results in reduced acuity, decreased contrast discrimination, and increased glare, all of which suggests that larger print should be used for textual warnings than is commonly employed on product labels. Some persons cannot hear well; thus, auditory warnings need to be distinctly discriminable (in loudness and tonal quality) from background noise. These are just a sample of considerations based on sensory capabilities. Other considerations are cognitive. People may be limited in their ability to understand technical information. Consider that the U.S. population now includes many Spanish speakers. Lim and Wogalter (2003) found that although many English language users in the United States believe that immigrants should learn English, most acknowledge that safety communications might also need to be in Spanish.

When and Where to Warn The placement of a warning in time and location is important. The warning should be available when and where it is needed. Having read a warning on a previous occasion does not mean that it will be remembered or that it will transfer to the current situation. In general, the preferred location for a product warning is on the product, but this location may not always be possible. Space constraints or the nature of the product (e.g., a small clamp) may impose such limits. Determination of potential locations for the warning generally requires a task analysis (Frantz and Rhoades, 1993). Later in the chapter some solutions to these problems are offered.

3 COMMUNICATION-HUMAN INFORMATION PROCESSING MODEL

In this section a theoretical context is presented that will serve as an organizing framework for reviewing some of the major concepts and findings regarding factors that influence warning effectiveness. Specifically, a communication-human information processing (C-HIP) model is described. First, a few comments about communications and human information processing.

Communications Warnings are a form of safety communications. Communication models were around for most of the twentieth century (Lasswell, 1948; Shannon and Weaver, 1949). A typical, very basic model shows a sequence starting with a source, who encodes a message into a channel that is transmitted to a receiver, who receives a decoded version of that message. Noise may enter into the system at several points in the sequence, reducing the correspondence between the message sent and the one received. The warning sender may be a product manufacturer, government agency, employer, or other. The receiver is the user of the product, the worker,

or any other person at risk. The message, of course, is the safety information to be communicated. The medium refers to the channels or routes through which information gets to the receiver from the sender. Understanding and improving these components of a safety communication system increases the probability that the message will be conveyed successfully.

However, the communication of warnings is seldom as simple as implied by a sequential communication model. Frequently, more than one medium or channel may be available and/or involved; multiple messages in different formats and/or containing different information may be called for, and the receiver or target audience may include different subgroups with varying characteristics. An example of such a warning situation would occur when a product with associated hazards is being used in a work environment. Figure 1 illustrates a communication model that might be applicable. It shows the distribution of safety information from several entities to the receiver and that feedback may influence the kind of safety information given. It also shows that in addition to the sender (manufacturer) and receiver (end user), other people or entities may be involved, such as distributors and employers. Further, each of these entities may be both receivers and senders of safety information. There are also more routes through which warnings may travel, such as from the manufacturer to the distributor to the employer to the user, from the manufacturer to the employer to the user, or directly from the manufacturer to the user (as on a product label). The warnings may take various forms. One example is safety rules that an

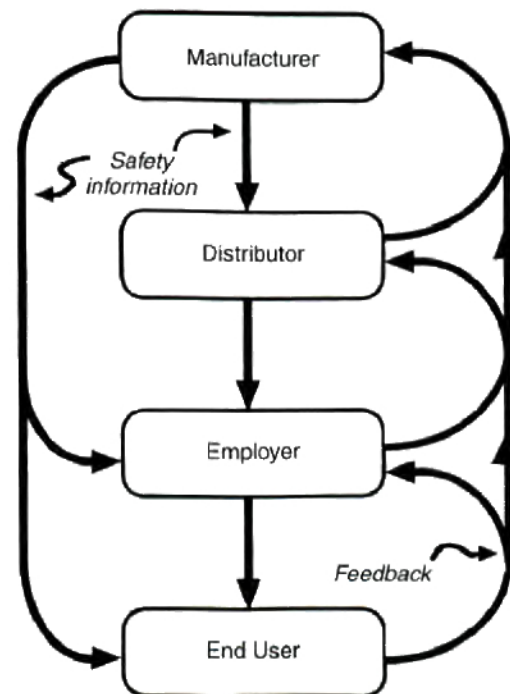


Figure 1 Distribution of safety information and feedback.

employer sets to govern the behavior of employees. By collecting feedback information, the warnings can be adjusted to meet criteria such as comprehension. Thus, warnings or warning systems may be much more complex than just a sign or label. Warning systems as a concept is discussed in more detail later in the chapter.

Human Information Processing Cognition is a core area of psychology that is concerned with mental processes such as attention and memory. Since the 1960s, much of the theoretical work has been described in terms of stages of processing. Numerous models have been developed and tested, with recent versions becoming more complex. Central to this activity has been the notion of stages. In the next section, a model that incorporates some basic stages of mental processing is described. It can be viewed as an elaboration of the communication model's receiver stage.

C-HIP Model The communications-human information processing model (Wogalter et al., 1999a) is a framework for showing stages of information flow from a source to a receiver, who in turn may cognitively process the information subsequently to produce compliance behavior. The model is displayed in Figure 2. The conceptual stages of source, channel, and receiver are taken from a very simple communication model. The receiver stage is divided into several human information processing substages prior to carrying out the compliance behavior. These substages are attention switch, attention maintenance, comprehension, attitudes and beliefs, and motivation.

At each stage of the model, warning information is processed and, if successful at that stage, "flows through" to the next stage. If processing at a stage is unsuccessful, it can produce a bottleneck, blocking the flow from getting to the next stage. This is the weak-link-in-the-chain phenomenon. If all the stages are successful, the process ends in behavior (compliance). Although processing of the warning might not make it all of the way to the last stage, it still may be effective at influencing earlier stages. For example, a warning might positively influence comprehension but not change behavior. Such a warning cannot be said to be totally "ineffective," since it produces better understanding and potentially can lead to better, more informed decisions. However, it is ineffective in the sense that it does not curtail unsafe behavior.

The C-HIP model can be particularly useful describing the factors that influence warning effectiveness. It also can be helpful in diagnosing and understanding warning failures and inadequacies. If a source (or sender) does not issue a warning, no information will be transmitted and thus nothing will be communicated to the receiver. Even if a warning is issued by the source, it will not be effective if the channel or transmission medium is poorly matched with the message, the receiver, or the environment. Each of the processing stages within the receiver can also produce a bottleneck, preventing further processing. The receiver might not notice the warning and thus not be

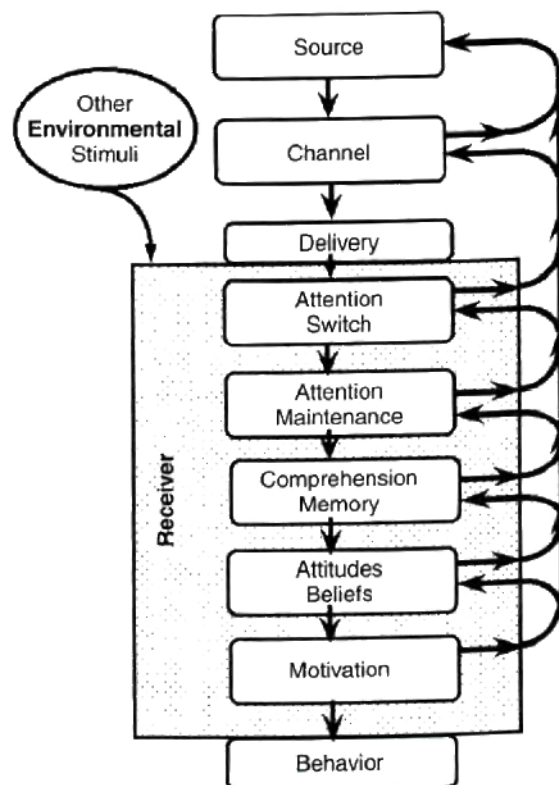


Figure 2 Communication-human information processing (C-HIP) model.

directly affected. Even if the warning is noticed, the individual may not maintain attention to the warning to encode the information. If the receiver encodes the details of the warning, it still may not be understood. If understood, it still might not be believed; and so on.

Although the processing described above is linear, there are feedback loops from later stages to earlier stages, as illustrated in Figure 2. For example, when a warning stimulus becomes habituated from repeated exposures over time, attention is less likely to be allocated to the warning on subsequent occasions. Here, memory (as part of the comprehension stage) affects an earlier attention stage of processing. Another example is that some people might not believe that a product or situation is hazardous, and as a consequence, not look for a warning. A third example is that the person may not understand the warning and therefore switch attention to read it again. These nonlinear effects between the stages resulting from feedback show how later stages influence earlier stages in ongoing cognitive processing.

In the sections that follow, each stage of the C-HIP model is described with some of the factors that influence it. The purpose is to assist in analyzing how or why warnings may fail or, conversely, what they have to accomplish to succeed. In many respects the model is similar to the information-processing

models employed by others (Lehto and Miller, 1986; Lehto and Papastavrou, 1993; Rogers et al., 2000). The model given here is somewhat different from the ones given in Wogalter et al. (1999a) and Wogalter and Laughery (2005). Two main differences are the inclusion of other environmental influences, and the need to deliver the message to the receiver. The purpose of including these additional elements is to emphasize their impact on the warning processes. An additional minor change is that attention is explicitly split into two distinct stages of switch and maintenance. Table 1 gives a summary of some of the primary considerations associated with successful processing at each stage.

3.1 Source

The source is the originator or initial transmitter of the warning information. The source can be a person(s) or an organization (e.g., company or government). Research shows that differences in the perceived characteristics of the source can influence people's beliefs about the credibility and relevance of the warning (Wogalter et al., 1999b). Information from a reliable, expert source (e.g., the Surgeon General, the U.S. Food and Drug Administration) is given greater credibility, particularly when the expertise is relevant (e.g., the American Medical Association for a health-related warning) (Wogalter et al., 1999b). An important aspect that is discussed in more detail later is that a warning attributed to an expert source may aid in changing erroneous beliefs and attitudes that the receiver may have.

A critical role of the source is to determine if there is a need for a warning and if so, what should be warned. This decision typically hinges on the outcome of hazard analyses that determine foreseeable ways injuries could occur.

There are several principles or rules that guide when a warning should be employed: (1) a significant hazard exists; (2) the hazard, consequences, and appropriate safe modes of behavior are not known to the persons at risk; (3) the hazards are not open and obvious (i.e., the appearance of the product or environment does not communicate them); and (4) a reminder is needed to assure awareness of the hazard at the proper time. There are other considerations in deciding what to warn about, such as the likelihood of an undesirable event and the severity of the potential outcomes.

Assuming that the product or environment is determined to need a warning, one or more channels of communication must be used to reach the receiver.

3.2 Channel

The channel is the way or medium in which information is transmitted from the source to one or more receivers. Warnings can be presented on product labels, on posters, in brochures, as part of audio-video presentations, given orally, and so on. Most commonly, warnings are sent via the visual (printed text warnings and pictorial symbols) and auditory (alarm tones, live voice, and voice recordings) modalities as opposed to

the other senses. There are exceptions: an odor added to flammable gases such as propane makes use of the olfactory sense, and a pilot's control stick that is designed to vibrate when the aircraft begins to stall makes use of the tactile and kinesthetic senses.

3.2.1 Media and Modality

There are two basic dimensions of the channel. The first concerns the media in which the information is embedded. The second dimension of the channel is the sensory modality used to capture the information by the receiver. Media and modalities are closely tied. Some studies have examined whether presentation of a language-based warning is more effective when presented in the visual (text) vs. the auditory (speech) modality. The results are conflicting (although generally either one is better than no presentation whatsoever). Some cognitive research (Penney, 1989) suggests that longer, more complex messages may be better presented visually and shorter messages auditorily. The auditory modality is better for attracting attention (a stage described below). However, auditory presentation can be less effective than visual presentation, particularly for processing lengthy, complex messages because (1) it is primarily temporal/sequential in nature, (2) its processing speed is slower, and (3) the ability to review previously presented material is often not possible. These characteristics tend to overload working memory (or maintenance attention, to be discussed later).

3.2.2 Multiple Methods and Redundancy

Research has generally found that presenting warnings in two modalities is better than one modality. Thus, a video-based warning is better if the words are shown on the screen while the same information is given orally. This method provides redundancy. If a person is not watching the screen, people can still hear it. If the person is blind or deaf, the information is available in the other modality. A similar concept for media is described in the next section.

3.2.3 Warning System

The idea that a warning is only a sign or a portion of a label is too narrow a view of how such safety information gets transmitted. Warning systems for a particular environment or product may consist of a number of components. In the context of the communication model presented in Figure 1, the components may include a variety of media and messages.

A warning system for an over-the-counter (OTC) pharmaceutical product such as a multisymptom cold medication may consist of several components: a printed statement on the box, a printed statement on the bottle, and a printed package insert. In addition, there may be text and/or speech warnings in television advertisements about the product. A warning system for pneumatic tools regarding the hazard of long-term vibration exposure causing damage to the nervous and vascular systems of the hand (vibration-induced white

Table 1 Methods and influences of the Communication-Human Information Processing (C-HIP) Stages

C-HIP Stage	Methods and Influences
Source	Determines that hazard is not designed out or guarded. Credible, expert.
Channel	Visual (signs, labels, tags, inserts, product manuals, video, etc.). Auditory (simple and complex nonverbal; voice; live or recorded). Other senses: vibration, smell, pain. Generally, transmission in more than one modality is better.
Delivery	Make sure that message gets to target audience(s).
Receiver	Consider demographics of target audiences (e.g., older adults, illiterates, cultural and language differences, persons with sensory impairments).
Attention switch	Should be high salience (conspicuous/prominent) in cluttered and noisy environments. Visual: high contrast, large. Presence of pictorial symbols aids noticeability. Auditory: louder and distinguishable from surround. Present when and where needed (placed proximal in time and space). Avoid habituation by changing stimulus.
Attention maintenance	Enables message encoding by examining/reading or listening. Visual: legible font and symbols, high-contrast aesthetic formatting, brevity. Auditory: intelligible voice, distinguishable from other sounds.
Comprehension and memory	Enables informed judgment. Understandable message provides necessary information to avoid hazard. Try to relate information to knowledge already in users' heads. Explicitness enables elaborative rehearsal and storage of information. Pictorials can benefit understanding and substitute for some wording; may be useful for certain demographic groups. At subsequent exposures, warning can cue or remind user of information. Comprehension testing needed to determine whether warning communicates intended/needed information.
Beliefs/attitudes	Familiarity reduces perceived hazard and warning processing. Persuasive argument and excellent warning design needed when beliefs are seriously discrepant with truth. May influence receiver's earlier stages.
Motivation	Energizes person to carry out next stage. Low cost (time, effort, money) facilitates compliance. Perceived high cost increases likelihood of noncompliance. Benefited by warning explicitness and perceived injury severity. Affected by social influence, time stress, mental workload.
Behavior	Carrying out safe behavior that does not result in injury or property damage.

finger) might consist of a number of components. Examples include warnings embossed on the tool, a removable tag attached to the product when new, accompanying sheets or a stapled manual, and printing on the box. In addition, manufacturers might provide employers with supplemental materials such as videos and posters to assist in employee training sessions. Organizations, including government agencies and consumer and trade groups, could provide additional materials. With the growing use of the Internet, information may be made available on Web sites. Another example would be warnings for a solvent used in a work environment for cleaning parts. Here the components might include printed on-product labels, printed flyers that accompany the product,

statements in advertisements about the product, verbal statements from the salesperson to the purchasing agent, and material safety data sheets provided to the employer.

The components of a warning system may not be identical in terms of content or purpose. For example, some components may be intended to capture attention and direct the person to another component, where more information is presented. Similarly, different components may be intended for different target audiences. In the example of the solvent above, the label on the product container may be intended for everyone associated with the use of the product, including the end user, whereas the information in the material safety data sheet (MSDS) may be directed

more to fire personnel or to an industrial toxicologist or safety engineer working for the employer (Smith-Jackson and Wogalter, in press).

3.2.4 Direct and Indirect Communications

The distinction between direct and indirect effects of warnings concerns the routes by which information gets to the target person. A direct effect occurs as a result of the person being exposed directly to the warning. That is, he or she reads or hears the warning directly. But warnings can also accomplish their purposes when delivered indirectly. One example is the woman who did not read the warnings about Toxic Shock Syndrome on a tampon box, but learns about the hazard in a conversation with her neighbor. The employer or physician who reads warnings and then communicates the information verbally to employees or patients is another example. Moreover, the print and broadcast news media may present information that is given in warning labels. The point is that a warning put out by a manufacturer may have utility even if the consumer or user is not exposed to the warning directly.

An example of where an indirect effect was considered in the design of a product warning concerned a herbicide used in agricultural settings. Given that significant numbers of farmworkers in parts of the United States read Spanish but not English, there was reason to put the warning in both languages. However, there are sometimes space constraints on product containers. One suggested strategy was to include a short statement on the label in Spanish indicating that the product was hazardous and that the user should get someone to translate the rest of the label before using the product.

There are situations where we rely on indirect communications to transmit warning information. Employers and physicians are examples already noted; adults who have responsibility for the safety of children are another important category. In the design of warning systems, empowering indirect warnings could enhance the spread of warning information to relevant targets.

3.3 Delivery

Although the source may try to disseminate warnings in one or more channels, the warnings might not reach some of the targets at risk. For example, a safety brochure that is developed and produced by a governmental agency that is never distributed is not very helpful. Purchasers of used products are at risk because the manufacturer's product manual is frequently not available or is not transferred to new owners at resale (Rhoades et al., 1991; Wogalter et al., 1998b). Without the manual, the user may not know what the correct and incorrect uses of the product are or what the maintenance schedule is, both of which could affect safety. Williamson (2006) describe problems associated with communicating warnings on the flash-fire hazard associated with burning plastic-based insulation. Although some warnings accompany bulk lots of insulation when shipped from

the manufacturer/distributor to job sites and some technical warnings may be seen by architects and high-level supervisors, the warnings infrequently make it downstream to construction workers who may be working with or around the product. The point here is that although a warning may be put out by a source (through some channel), it may have limited utility if it does not reach the targets at risk either directly or indirectly.

3.4 Receiver

In this section we focus on the receiver; that is, the person(s) or target audience to whom the warning is directed. As noted earlier, the primary theoretical context for presenting this analysis is an information-processing model. This model with respect to the receiver, shown in Figure 2, defines a sequence of processing stages through which warning information flows. By examining each of the stages and the factors that influence success or failure at each stage, a better understanding of how warnings should be designed and whether they are likely to be effective can be attained.

For a warning to communicate information and influence behavior effectively, attention must be switched to it and then maintained long enough for the receiver to extract the necessary information. Next, the warning must be understood and must concur with the receiver's existing beliefs and attitudes. If there is disagreement, the warning must be sufficiently persuasive to evoke an attitude change toward agreement. Finally, the warning must motivate the receiver to perform proper compliance behavior. The next several sections are organized around these stages of information processing.

3.4.1 Attention

One of the goals of a warning is to capture attention and then hold it long enough for the contents to be processed. In the following sections we address these two attention issues.

Switch of Attention The first stage in the human-information-processing portion of the C-HIP model concerns the switch of attention. An effective warning must initially attract attention. Often, this attraction must occur in environments that also have other stimuli competing for attention.

For a warning to capture attention, it must first be available to the recipient. As noted earlier, warning messages that do not arrive at the end user will not have direct effects. Assuming that the warning is present, it needs to be sufficiently salient (conspicuous or prominent) to capture attention. Warnings typically have to compete for attention, and several design factors influence how well they compete.

Size and Contrast Bigger is generally better. Increased print size and contrast against the background have been shown to benefit subsequent recall (Barlow and Wogalter, 1993). Young and

Wogalter (1990) found that print warnings with highlighting and bigger, bolder print led to higher comprehension of and memory for owner's manual warnings.

Context plays an important role with regard to size effects on salience. It is not just the size of the warning that is important, but also its size relative to other information in the display. A bold warning on a product label where there are other informational items in larger print is less likely to be viewed than those larger items.

For some products, the available surface area on which warnings can be printed is limited. This is particularly true for small product containers such as pharmaceuticals. Methods available to increase the surface area for print warnings include adding tags or peel-off labels (Barlow and Wogalter, 1991; Wogalter et al., 1999d). Another method is to put some minimum critical information on a primary label and direct the user to additional warning information in a secondary source, such as in a well-designed owner's manual or package insert. Wogalter et al. (1995) have shown that such a procedure can be effective.

Color Although there are some problems with the use of color, such as color blindness, fading, and lack of contrast with certain other colors, people are generally strongly in favor of the use of color. A colored signal word attracts attention more effectively than one that is black like the rest of the print (e.g., Laughery et al., 1993b). The ANSI Z535 (2002) standard relies on color in the signal word panel to attract attention.

Pictorial Symbols Pictorial symbols can be useful for capturing attention (Jaynes and Boles, 1990; Young and Wogalter, 1990; Laughery et al., 1993a; Kalsher et al., 1996; Bzostek and Wogalter, 1999). One general symbol that attracts attention is the alert icon (triangle enclosing an exclamation point) (Laughery et al., 1993a) that is found in the signal word panel in ANSI (2002) Z535-style warnings.

Placement A general principle is that warnings located close to the hazard, both physically and in time, will increase the likelihood of a proper attention switch (Frantz and Rhodes, 1993; Wogalter et al., 1995). A warning on the battery of a car regarding a hydrogen gas explosion hazard is much more likely to be effective than a warning in the car owner's manual. A verbal warning given two days ago before a farmworker uses a hazardous pesticide is less likely to be remembered and effective than one given immediately prior to using the product.

A warning, even a good one, that is located in a out-of-view location reduces its likely effectiveness drastically. In general, placement of warnings directly on a hazardous product is preferred (Wogalter et al., 1987). However, there are several factors to be considered in warning placement. One is visibility: A warning should be placed so that users are likely to see it (Frantz and Rhoades, 1993). For example, a warning on one side of a tall rolling cart (with a high center of gravity) may not be seen if the user does

not examine that side of the cart before use. People generally do not read owner's manuals of cars they rent; thus, if not given some better way of warning about the particulars of the vehicle, such as a special stickers or a quick-tip chart, drivers will not be aware of important safety information. Manufacturers need to consider how their product may be used so they can be better prepared to select proper locations for warnings. In general, warnings should be located near other information that will be needed to perform a task. Task analyses are likely to be beneficial here.

With most languages, people tend to scan printed material left to right and top to bottom. Thus, warnings should be located near the top or to the left and not be buried in the middle or at the bottom. Wogalter et al. (1987) showed that warnings in a set of instructions for mixing chemicals were more likely to be noticed and complied with if placed before the task instructions than if following them.

Related to the concern about warning locations, however, is the fact that at times practical considerations limit the options. A small container such as on some over-the-counter medications may simply not have room for all of the information that should go into the warning. Some options for this problem are discussed later.

Formatting Another factor that can influence attention is formatting. Visual warnings that are formatted to be aesthetically pleasing, with plenty of white space and coherent information groupings (Hartley, 1994), are more likely to attract attention (Wogalter and Vigilante, 2003). If a warning contains large amounts of text, people may decide that too much effort is required to read it, and direct their attention to something else.

Repeated Exposure A related issue is that repeated and long-term exposure to a warning may result in a loss of attention-capturing ability (Wogalter and Laughery, 1996). This habituation can occur over time, even with well-designed warnings. Where feasible, changing a warning's format or content can slow the habituation process (Wogalter and Brelsford, 1994). We discuss habituation in more detail in a later section.

Other Environmental Stimuli Other stimuli in the environment may compete with the warning for attention capture. Other stimuli may include the presence of other persons, various objects that comprise the context, and tasks the person is performing. Thus, the warning must stand out from the background (i.e., be salient or conspicuous) in order to be noticed. This factor is particularly important because people typically do not actively seek hazard and warning information. Usually, people are focused on the tasks they are trying to accomplish. Safety considerations that may be important to a person are simply not always on one's mind. Hence, the warning needs to be conspicuous.

Auditory Warnings Auditory warnings are frequently used to attract attention. Auditory signals are

omnidirectional, so the receiver does not have to be looking at a particular location to be alerted. Like print warnings, their success on the attention criterion is largely a matter of salience. Auditory warnings should be more intense and distinctively different from expected background noise. Often, auditory warnings are used in conjunction with visual warnings, with the auditory warning serving to call attention to the need to read or examine a visual/written warning that contains specific information.

Maintenance of Attention People may notice the presence of a warning but not stop to examine it. A warning that is noticed but fails to maintain attention long enough for its content to be encoded is of little direct value. Attention must be maintained on the message for some length of time to extract meaning from the material (Wogalter and Leonard, 1999). During this process, the information is encoded or assimilated with existing knowledge in memory.

With brief warnings the message information may be acquired very quickly, sometimes as fast as a glance. For longer warnings to maintain attention, they need to have qualities that generate interest and do not require considerable effort. Some of the same design features that facilitate the switch of attention also help to maintain attention. For example, large print not only attracts attention, but also increases legibility, thus making reading less effortful and more likely.

Legibility If the warning has very small print, it may not be legible, making it difficult to read. Some persons may not be able to read it even with visual correction, and some who might be able to read it with some effort will not. Older adults with age-related vision problems are a particular concern (Wogalter and Vigilante, 2003). Distance and environmental conditions such as fog, smoke, and veiling glare can affect legibility.

Sanders and McCormick (1993) give data on the legibility of fonts developed for military applications. Legibility of type can be affected by numerous factors, including choice of font, stroke width, letter compression and distance between them, case, resolution, and justification. Although there is not much research to support a clear preference for the use of certain fonts in warnings over others, the general recommendation is to use relatively plain, familiar fonts. It is sometimes recommended that a serif font such as Times or Times Roman be used for small-sized text and a sans-serif font such as Universe or Helvetica be used in applications requiring headline type sizes. The ANSI (2002) Z535.2 and Z535.4 standard documents have a chart of print size and expected reading distances in good and degraded conditions.

Contrast and color is another consideration. Black on white or the reverse has the highest contrast, but legibility can be adequate with other combinations, such as black print on yellow and white print on red. The selection of color should also be governed by the context in which the warning is presented (Young, 1991). One would not want to put a red and white warning on a largely red background.

Formatting People are more likely to maintain attention if a warning is "readable" with respect to layout. Visual warnings formatted to be aesthetically pleasing are more likely to hold attention (and thus be examined and the information extracted) than is a single chunk of dense text (Wogalter and Vigilante, 2003). Formatting can show the organization of the warning material, making it easier to assimilate or accommodate into memory. In general, the use of generous white space and bulleted lists are preferred to long, dense paragraphs (Desaulniers, 1987; Wogalter and Post, 1989). Although aesthetically pleasing at a distance, full justification (the straight alignment of the beginning and ending words at both margins) is more difficult to read than "ragged right" (justification only of the left margin), where the spacing between letters and words is consistent.

Pictorial Symbols Interest is also facilitated by the presence of well-designed pictorial symbols. Further, research indicates that people prefer warnings that have a pictorial symbol to warnings without one (Young et al., 1995; Kalsher et al., 1996).

Auditory Warnings Simple nonverbal auditory warnings are generally used as alert (attention-getting) signals. Frequently, these signals carry very little information other than an attention-switch cue. After the alert is given, the visual modality is generally used to access further information (Sorkin, 1987; Sanders and McCormick, 1993).

3.4.2 Comprehension

Comprehension concerns one's ability to grasp the meaning of a warning. Some comprehension may derive from subjective understanding such as its hazard connotation, and some from more direct understanding of the language and the symbols used.

Hazard Connotation The idea of hazard connotation is that certain aspects of the warning may convey some level or degree of hazard. It is an overall perception of risk, a subjective understanding of the danger conveyed by the warning components. A similar type of connoted hazard was shown in research by Wogalter et al. (1997) for various container types.

In the United States, current standards such as ANSI (2002) Z535 and guidelines (e.g., Westinghouse Electric Corporation, 1981; FMC Corporation, 1985) recommend that warning signs and labels contain a signal word panel that includes one of the terms DANGER, WARNING, or CAUTION. According to ANSI Z535, these terms are intended to denote decreasing levels of hazard, respectively. Figure 3 shows two ANSI-type warning signal word panels. According to ANSI Z535, the DANGER panel should be used for hazards where serious injury or death will occur if warning compliance behavior is not followed, such as around high-voltage electrical circuits. The WARNING panel is used when serious injury might occur, such as severe chemical burns or exposure to highly flammable gases. The CAUTION panel is used when less severe personal injuries or damage to



Figure 3 Two signal word panels including alert symbol and color. Note that the DANGER panel is white print on a red background, and the CAUTION is black print on a yellow background. Not shown is the WARNING panel, which is black print on an orange background.

property might occur, such as getting hands caught in operating equipment. Research shows that laypersons often fail to differentiate between CAUTION and WARNING, although both are interpreted as connoting lower levels of hazard than DANGER (e.g., Wogalter and Silver, 1995). The term NOTICE is intended for messages that are important but do not relate to injuries. The term DEADLY, which has been shown in several research studies to connote hazard significantly above DANGER, has not been adopted by ANSI, yet might be considered for hazards that are significantly above those using the term DANGER.

Different characteristics of sounds can lead to different hazard connotations. Sounds that are more intense, of higher frequency, or have rises in pitch and/or faster beats can cue greater perceived hazard urgency (Edworthy et al., 1991). The same effects are true with voice (Barzegar and Wogalter, 1998; Hollander and Wogalter, 2000; Weedon et al., 2000; Hellier et al., 2002).

According to the ANSI standard, the signal words DANGER, WARNING, AND CAUTION are to be accompanied by specific colors (red, orange, and yellow, respectively). This assignment provides redundancy. However, the colors for WARNING (orange) and CAUTION (yellow) are not readily distinguished with regard to hazard connotation, although red (for DANGER) generally has a significantly higher hazard connotation than the other two colors (e.g., Chapanis, 1994). Color can also be used to change the hazard connotation. For example, the signal word DANGER with the color orange connotes less hazard than the same term with the color red.

Competence There are many dimensions of receiver competence that may be relevant to the design of warnings. For example, sensory deficits might be a factor in the ability of some special target audiences to be directly influenced by a warning. A blind person would not be able to receive a written warning, nor would a deaf person receive an auditory warning.

At the opposite end of the sequence of events is behavior. If special equipment is required to comply

with the warning, it must be available or obtainable. If special skills are required, they must be present in the receiver population. It is not difficult to find examples of warnings that violate considerations of people's limitations. One example is the common warning instruction on containers of solvents: "Avoid breathing fumes." This instruction can be difficult to carry out because users may not see or smell the vapors and appropriate respirator equipment may not be available.

Three characteristics of receivers related to cognitive competence are important in warning design: technical knowledge, language, and reading ability. The communication of hazards associated with medications, chemicals, and mechanical devices is often technical in nature. If the target audience does not have the relevant technical competence, the warning is not likely to be successful. The level or levels of knowledge and understanding of the audience must be taken into account. This point is discussed further in a later section.

The issue of language is straightforward, and it is increasingly important. Subgroups in the United States speak and read languages other than English, such as Spanish. As trade becomes more international, requirements for warnings to be directed to non-English readers will increase. Ways of dealing with this problem include warnings stated in multiple languages and the use of pictorials.

Reading ability is another target audience characteristic where its importance is obvious. Yet, high reading levels, such as a grade 12, are not uncommon for warnings intended for those with lower reading abilities. In general, reading level should be as low as feasible. For general target audiences, the reading level might need to be in the range grade 4 to 6. Clearly, if comprehension of a warning is to be achieved, reading levels must be consistent with reading abilities of receivers. There are readability formulas or indices based on word frequency of use, length of words, number of words in statements, and so on, that are used to estimate reading grade level (Duffy, 1985). These formulas have limitations, such as being notorious for giving inaccurate estimates. However, they can be useful as a preliminary guide to achieving a warning that will be understood. A discussion of reading level measures and their application to the design of instructions and warnings may be found in Duffy (1985).

An additional point on reading ability concerns illiteracy. There are estimates that over 16 million functionally illiterate adults exist in the U.S. population. If so, successfully communicating warnings may require more than simply keeping reading levels to a minimum. Although simple solutions to this problem do not exist, pictorials, speech warnings, special training programs, and so on, may be important components of warning systems for such populations.

Message Content The content of the warning message should include information about the hazard, the consequences of the hazard, and instructions on how to avoid the hazard.

Hazard Information The point of giving hazard information is to tell the target audience what the safety problem is (i.e., what can go wrong). Generally, this information is specific to the environment or product. Examples are:

Toxic Vapors
Slippery Floor
High Voltage

A general principle is that the hazard should be spelled out in the warning. However, there are exceptions when the hazard is (1) general knowledge, (2) known from previous experience, or (3) "open and obvious" (the latter is a concept that is described in more detail in a subsequent section). Where these conditions do not exist, hazard information is an important part of the warning (Wogalter et al., 1987).

Consequences Consequences information concerns the nature of the injury, illness, or property damage that could result from a hazard. Hazard information and consequence information are usually closely linked in the sense that one leads to the other, or stating it in the reverse, one is the outcome of the other. In warnings, statements regarding these two elements should generally be sequenced; an example is

Toxic Vapor
Severe Lung Damage

For purposes of getting and holding the receiver's attention, however, there are situations where it is desirable to put consequences information near the beginning of the warning (just after the icon and signal word) in larger and bolder print (Young et al., 1995). This is particularly true for severe consequences such as death, paralysis, or severe lung damage. Hence, the hazard and consequence statements above might be better presented as

**Severe Lung
Damage**
Toxic Vapor

There are also occasions or situations when the hazard information is presented and understood, so it may not be necessary to state the consequences in the warning. This point is related to the open and obvious aspects of hazards. For example, a sign indicating "Slippery Floor" probably does not need to include a consequence statement "You Could Fall." It is reasonable to assume that people will correctly infer the appropriate consequence. Although it is desirable to keep warnings as brief as possible (the brevity criterion is discussed in a later section), there is a potential problem with omitting consequence information; specifically, people may not make the correct inference regarding injury, illness, or property damage outcomes. Thus, it is important in designing

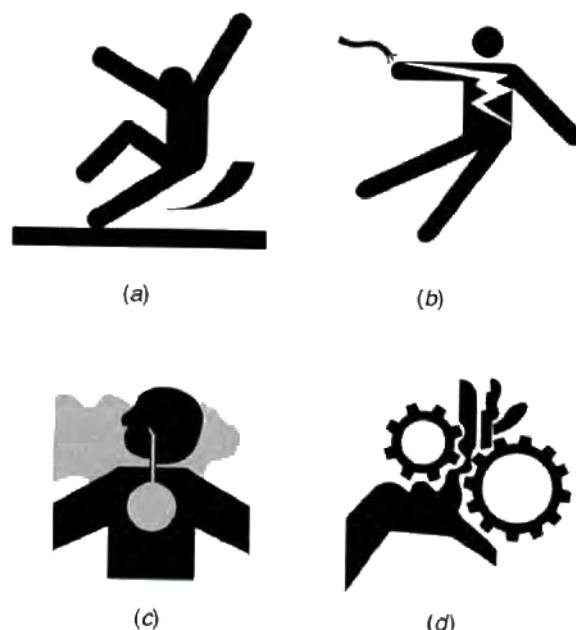


Figure 4 Pictorials conveying hazard information: (a) slippery floor; (b) electricity; (c) toxic gas; (d) pinch point.

warnings to assess, if necessary, whether people will infer the consequences correctly.

A common shortcoming of warnings is that consequences information is not explicit; that is, it does not provide important specific details. The statement "May be hazardous to your health" in the context of a toxic vapor hazard does not tell the receiver whether he or she may develop a minor cough or suffer severe lung damage (or some other outcome). This issue is discussed in Section 4.3. The point is that knowing about severe consequences can be a motivational factor in attending to and complying with the warning message, a consideration discussed further in Section 3.4.4.

Pictorials can also be used to communicate consequence information. Some pictorials (e.g., for a slippery floor hazard) convey both hazard and consequence information without it being stated directly. Examples are shown in Figure 4.

Instructions In addition to getting people's attention and telling them what the hazard and potential consequences are, warnings should instruct people about what to do or not do. Typically, but not always, instructions in a warning follow the hazard and consequence information. An example of an instructional statement that might go with the hazard and consequence statements above is

Severe Lung Damage
Toxic Vapors
Must Use Respirator Type 1234

This instruction assumes, of course, that the receiver will know what a Type 1234 respirator is and have access to one.

Pictorials can be used to communicate instructions. Figure 5 shows examples of instructional information used in warnings. Note that some pictorials use a prohibition symbol, a circle containing the pictorial with a slash through it. Both the circle and slash are usually red, although sometimes they are black.

Sometimes a distinction is made between warnings and instructions. Warnings are communications about safety; instructions may or may not concern safety. "Keep off the grass" is an instruction that generally has nothing to do with safety (unless the grass is infested with fire ants, in which case the statement alone clearly would not be an adequate warning). When instructions are concerned with safety information or safe behavior, they can be viewed as part of a warning. In short, warnings include instructions, but not all instructions are part of a warning.

Explicitness An important design principle relevant to warning comprehension is explicitness (Laughery et al., 1993a). Explicit messages contain information that is sufficiently clear and detailed to permit the receiver to understand at an appropriate level the nature of the hazard, the consequences, and the instructions. The key here is the word *appropriate*. A classic example is: "Use with adequate ventilation." Does this statement mean open a window, use a fan, or something much more technical in terms of volume of air-flow per unit time? Obviously, the instruction is not clear. Warnings are frequently not detailed or specific

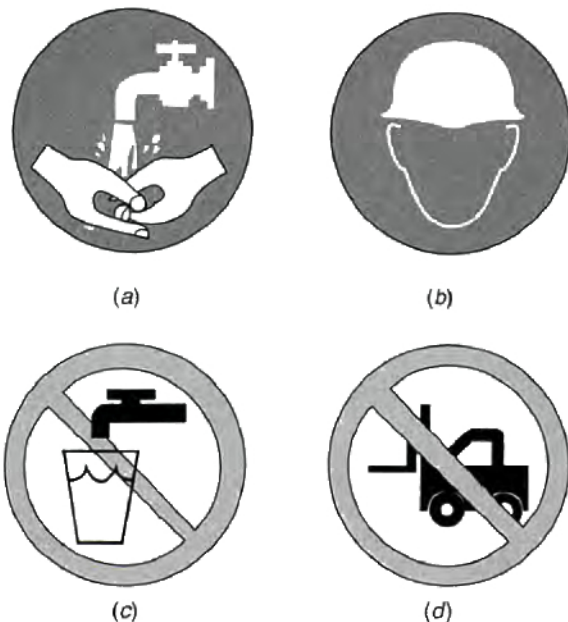


Figure 5 Pictorials conveying instructional information: (a) wash hands; (b) wear hard hat; (c) do not drink water; (d) do not use forklifts in area.

enough. However, sometimes, as stated earlier, technical details are not necessary and may be detrimental. The following two examples are warnings with hazard, consequence, and instructional statements that are not sufficiently explicit.

**Dangerous Environment
Health Hazard
Use Precaution**

**Mechanical Hazard
You Could Be Injured
Exercise Care**

Alternatives to the above that would be considered more explicit and appropriate are:

**Severe Lung Damage
Toxic Vapors
Must Use Respirator Type 1234**

**Pinch Point Hazard – Moving Rollers
Hand May Be Severely Crushed or Amputated
Do Not Operate Without Guard X In Place**

Pictorial Symbols Pictorial symbols are used to communicate hazard-related information, often in conjunction with the printed text message. Guidelines such as ANSI (1991) and FMC Corporation (1985) place considerable emphasis on the use of safety symbols. Pictorials are particularly useful in helping to increase comprehension (Lerner and Collins, 1980; Collins, 1983; Zwaga and Easterby, 1984; Boersema and Zwaga, 1989; Laux et al., 1989; Wolff and Wogalter, 1993, 1998; Dewar, 1999). They can contribute to understanding when illiterates or non-English readers are part of the target audience. Also, they can be useful where there are time constraints, such as traveling on a highway, because well-designed pictorials can cue large amounts of knowledge in a glance.

Although pictorials can assist in the comprehension of warning information, comprehension is also a primary concern or criterion for pictorials. In some pictorials, the depiction directly represents the information or object being communicated and will be understood if the person recognizes the intended depiction. Figure 6 shows two examples of direct representation. One shows both a hazard and consequences by depicting a raging fire, and the other shows both the hazard and the instructions, depicting the need for an eye shield. In other pictorials, the symbol may be recognized but its meaning has to be learned. People may recognize a skull and crossbones, but the fact that it represents a poison hazard would have to be learned. Some pictorials are completely abstract, such as the symbols for "do not enter" and biohazard shown in Figure 7, and must be learned to be understood. As

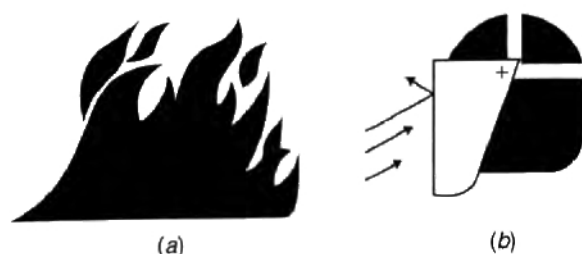


Figure 6 Pictorials showing a direct representation: (a) raging fire; (b) wear eye shield.

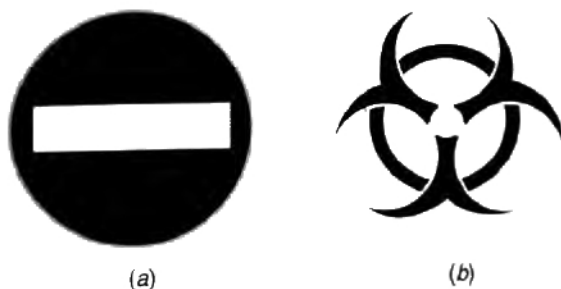


Figure 7 Pictorials that can be recognized after learning: (a) do not enter; (b) biohazard.

a general principle, pictorials containing symbols or pictures that directly represent the information are preferred, especially for general target audiences.

What is an acceptable level of comprehension for pictorials? This question has been addressed in the ANSI (2002) Z535 standard, which suggests a goal of 85% comprehension by the target audience. Two criteria seem relevant here. The first is simply that the pictorial should be designed to accomplish the highest level of comprehension attainable. If 85% cannot be achieved, it may still be useful, depending on the alternatives. A second criterion is that the pictorial not be misinterpreted or communicate incorrect information. According to the ANSI (2002) Z535 standard, an acceptable symbol must have less than 5% critical confusions (opposite meaning or a meaning that would produce unsafe behavior). Wogalter (1999) cites an example of a misinterpretation of a pictorial that was part of a warning for the drug Acutane. This drug is used for severe acne but causes birth defects in babies of women taking the drug during pregnancy. The pictorial shows a side-view outline shape of a pregnant woman within a circle-slash negation sign. The intended meaning of the pictorial is that women should not take the drug if they are pregnant. However, some women interpreted the symbol incorrectly to mean that the drug might help in preventing pregnancy.

Habituation Repeated exposure to a warning over time may result in its being less effective in attracting attention. Even a well-designed warning incorporating the features described in this chapter will eventually become habituated if encountered

repeatedly. Although the result implies that the person has learned the information, sometimes the warning may become habituated with only partial knowledge. Although habituation is a problem, warnings with the features described in this chapter are more likely to slow down the habituation process than warnings without the features. Although there are no easy solutions to this problem, one approach that may have some utility is to have warnings that vary from time to time. Rotational warnings such as on cigarette packages in the United States were intended to serve this purpose. However, these warnings have not changed in content or appearance in several decades, and regular smokers have probably habituated to them.

Memory and Experience There are several ways to enhance safety knowledge. Employer training, mentioned earlier, is one method. Experience is another way that people may acquire safety knowledge. "Learning the hard way" by having experienced an incident or personally knowing someone who did can certainly result in such knowledge. However, such experiences are not good experiences to have (!), and they do not necessarily produce accurate perceptions of risk. We discuss this topic in more detail in Section 3.4.3.

Warnings as Reminders Although people may have knowledge of a hazard, they may not be aware of it at the time they are at risk. In short, there is a distinction between awareness and knowledge. This distinction is analogous to the short- and long-term memory distinction in cognitive psychology. Short-term or working memory is sometimes thought of as consciousness, whereas long-term memory is one's knowledge of the world. The point is that people may have information or experience in their overall knowledge base, but at a given time, it is not part of what they are thinking about. It is not enough to say that people know something. Rather, it is important that people be aware of (be thinking about) the relevant information at the critical time. No one knew better than the three-fingered punch press operators of the 1920s that their hand should not be under the piston when it stroked, but such incidents continued to occur. The solution was an engineering control, requiring guards to be in place for the press to punch. Thus, the distinction between knowledge and awareness has implications for the role of warnings as reminders, where their presence may cue information in long-term memory so as to bring forth related, previously dormant knowledge into conscious awareness.

There are several circumstances in which warning reminders are useful and/or needed. Some of the more noteworthy are when (1) a hazardous situation or product (that is not open and obvious) is encountered infrequently, and forgetting may be a factor; (2) distractions occur during the performance of a task or the use of a product (e.g., environmental stimuli); and (3) heavy task loads exceed attentional capacity to access related knowledge (high mental workload and involvement in the task).

When warnings are intended only to function as reminders, it generally is not necessary to provide the same amount of information that would normally be required. Here the emphasis should be more on noticeability, getting the person's attention. The key point in considering the need for reminder warnings is to keep in mind that hazard knowledge on the part of a target audience (e.g., through prior training) does not guarantee that the relevant knowledge will be available when needed.

"Open and Obvious" A source of information about dangers is the situation or product itself. In U.S. law there is a concept of "open and obvious." This concept means that the appearance of a situation or product or the manner in which it functions may communicate the nature of the safety problem. For example, it is apparent to all but the youngest children that a knife can cut. The hazard and consequence of a fall from a height in a construction setting is open and obvious. Of course, many hazardous situations are not open and obvious, such as those associated with many types of chemical hazards.

Technical Information Many warnings require an appreciation of technical information for full and complete understanding of the material. The chemical content of a toxic material, the maximum safe level of a substance in the atmosphere in parts per million (ppm), and the biological reaction to exposure to a substance are examples. Although there are circumstances where it is appropriate to communicate such information (e.g., to the toxicologist on the staff of a chemical plant or the physician prescribing medicine), as a general rule it is neither necessary nor useful to communicate such information to a general target audience. Indeed, it may be counterproductive in the sense that encountering such information may result in the receiver not attending to the remainder of the message. The end user of the toxic material typically does not need to know technical chemical information, such as its density in the atmosphere. Rather, he or she needs to be informed that the substance is toxic, what it can do in the way of injury or illness, and how to use it safely. Where there are multiple groups within the target audience (the toxicologist and the employee, the physician and the patient, the parent and the child), different components of the warning system can and often should be used to communicate to the different groups.

Auditory Warnings Besides simple auditory alerts described in Section 3.4.1, auditory warnings may be used for the specific purpose of conveying particular meanings. These auditory warnings may be nonverbal (different distinguishable sounds to cue different things) or verbal (speech/voice).

Nonverbal Warnings Nonverbal auditory warnings can be divided further into simple and complex. Such simple warnings were mentioned in the context of attention switch. Complex nonverbal signals are composed of sounds of differing (sometimes dynamically)

in amplitude, frequency, and temporal pattern. Their purpose is to communicate different levels or types of hazards. They can transmit more information than simple auditory warnings, but the listener must know what the auditory signal means. Training must be given to associate its meaning. Only a limited number of different complex signals should be used, usually not more than a few, because people are limited in discriminating and remembering them (Cooper, 1977; Banks and Boone, 1981).

Voice Warnings Complex warning messages can also be transmitted via voice (speech). In recent years, voice chips and digitized sound processors have been developed making voice warnings feasible for a wide range of novel approaches and applications. Under certain circumstances, voice warnings can be more effective than printed signs in transmitting information (Wogalter and Young, 1991; Wogalter et al., 1993a). Some problems are, however, inherently associated with voice warnings. Transmitting speech messages requires longer durations than simple auditory warnings or reading an equivalent message. Comprehension can also be a problem with complex voice messages. To be effective, voice messages should be intelligible and brief. Nevertheless, this medium for communicating safety information would appear to have considerable potential.

3.4.3 Beliefs and Attitudes

If a warning captures and maintains attention successfully and is understood, it still might fail to elicit safety behavior, due to discrepant beliefs and attitudes held by the receiver. Beliefs refer to a person's knowledge of a topic that is accepted as true. Attitudes are similar to beliefs but have greater emotional involvement (DeJoy, 1999). According to the C-HIP model, a warning will be processed successfully at this stage if it concurs with the receiver's current beliefs and attitudes. The warning message will tend to reinforce what the receiver already knows and in the process will tend to make those beliefs and attitudes stronger and more resistant to change. If, however, the warning information does not concur with the receiver's existing beliefs and attitudes, for it to be effective, the beliefs and attitudes must be altered by the warning. The warning must be salient and the message must be strong and persuasive to override preexisting beliefs and motivate compliance.

People's experiences with a situation or product can result in their believing that it is safer than it is. It can also be a problem when people believe that their own abilities or competence will enable them to overcome the hazard, such as the young adult male who believes that he can safely do a shallow dive into the shallow end of a swimming pool.

Risk Perception One of the important factors in whether people will read and comply with warnings is their perception of the level of hazard and consequences associated with the situation or product. The greater the perceived level of hazard and

consequences, the more responsive people will be to warnings (Wogalter et al., 1991, 1993b). Persons who do not perceive a product as being hazardous are less likely to notice or read an associated warning (Wogalter et al., 1991; Wogalter, 1993b). Perceived hazard is also closely related to the expected injury's severity level. The greater the potential injury, the more hazardous the product is perceived (Wogalter et al., 1991). Even if the warning is read and understood, compliance may be minimal if the level of hazard is believed to be low.

Familiarity Familiarity beliefs are formed from past similar experience where at least some relevant information has been acquired and stored in memory. Familiarity may produce a belief that everything that needs to be known about a product or situation is already known (Wogalter et al., 1991, 1993b). A person who is familiar with a piece of equipment might assume that a new, similar piece of equipment operates in the same way (which may not be true), thus reducing the likelihood that a warning would be read. Numerous studies have explored the effects of people's familiarity/experience with a product on how they respond to warnings associated with the product. Results indicate that the more familiar people are with a product, the less likely they are to look for, notice, or read a warning (Godfrey et al., 1983; Godfrey and Laughery, 1984; LaRue and Cohen, 1987; Otsubo, 1988; Wogalter et al., 1991). Some research has also examined the effects of familiarity on compliance (Goldhaber and deTurck, 1988; Otsubo, 1988). The results have shown that greater familiarity is associated with a lower likelihood to comply with warnings.

This notion "familiarity breeds contempt," however, should not be overemphasized for at least two reasons. First, people more familiar with a situation or product may have more knowledge about the hazards and consequences as well as an understanding about how to avoid them. Second, people in situations or using products more frequently are exposed to the warnings more often, which increases the opportunity to be influenced by them. Nevertheless, where familiarity is a factor, it should be realized that stronger warnings or perhaps other efforts will be required. Clearly, then, products that are used repetitively or used in highly familiar environments pose special warning challenges.

Prior experience can be influential in other ways. Having experienced some form of injury or having personal knowledge of someone else being injured has been shown to result in overestimating the degree of danger associated with some situation or product. Similarly, the lack of such experiences may lead to underestimating such dangers or not thinking about them at all (Wogalter et al., 1991, 1993b).

A related point concerns the problem of overestimating what people know. Experts in a domain may be so facile with certain knowledge that they fail to realize that nonexperts do not have similar skills and knowledge. To the extent that it is assumed incorrectly

that people have certain information and knowledge, there may be a tendency to provide inadequate warnings. Thus, an important part of job, environment, and product design is to take into account the target audience's understanding and knowledge of hazards and their consequences. Further discussion of this issue may be found in Laughery (1993).

3.4.4 Motivation

Even if people believe a warning, they may not comply. Motivation is tied very closely to the response end of the process leading to behavior. In some respects it is energizing to a person to carry out an activity that they might not otherwise do. Among the most influential factors for motivation with respect to warnings is the cost of compliance and the cost of noncompliance (severity of the potential injury, illness, or property damage). If the warning calls for actions that are inconvenient, time consuming, or costly, there is a likelihood that it will not be effective unless the consequences of noncompliance are perceived as being highly undesirable.

Cost of Compliance The cost associated with compliance can be a strong motivator. Generally, compliance with a warning requires that people take some action. Usually, there are costs associated with taking action. The cost of compliance may include time, effort, or even money to carry out the behavior instructed by the warning. When people perceive the costs of compliance to be greater than the benefits, they are less likely to perform the safety behavior. This problem is commonly encountered in warnings where the instructions given are inconvenient, difficult, or occasionally impossible to carry out. "Do not breathe vapors" clearly cannot be accomplished by stopping breathing. "Always have two or more persons to lift" is not possible if no one else is around. "Wear rubber gloves when handling this product" may be inconvenient if the user does not have them and the hardware store is two miles away.

Thus, the requirement to expend extra time or effort can reduce motivation to comply with a warning (Dingus et al., 1991; Wogalter et al., 1987, 1989). One way of reducing the cost of compliance is to make the directed behavior easier to perform. For example, if hand protection is required when using a product, gloves might accompany the product. The general rule is that safe use of a product should be as simple, easy, and convenient as possible.

The costs of noncompliance with a warning can also have a powerful influence on compliance motivation. This effect is particularly true when the possible consequences of the hazards are severe. As already discussed, possible injuries associated with noncompliance should be explicitly stated in the warning (Laughery et al., 1993a). Explicit injury-outcome statements such as "Can cause liver disease—a condition that almost always leads to death" provide reasons for complying and are preferred to general, nonexplicit statements such as "Can lead to serious illness." In a sense, compliance decisions can be viewed in part as a

trade-off between the perceived cost of noncompliance and the perceived cost of compliance.

Severity of Consequences An issue related to the costs of noncompliance is the severity of consequences. Perceived severity of injury is tied intimately to risk perception, as discussed in Section 3.4.3. Severity of injury is a major factor in reported willingness to comply with warnings. People's notions of hazardousness are based almost entirely on the seriousness of the potential outcome (Wogalter et al., 1991, 1993b). Further, people do not readily consider the likelihood or probability of such events in their hazard-related judgments (Wogalter and Barlow, 1990; Young et al., 1990, 1992). These findings emphasize the importance of clear, explicit consequences information in warnings. Such information can be critical to people's risk perception and their evaluation of trade-offs between cost of compliance and cost of noncompliance.

Social Influence and Stress Another motivator of warning compliance is social influence. Research (Wogalter et al., 1989) has shown that if people see others comply with a warning, they are more likely to comply themselves. Similarly, seeing others not comply lessens the likelihood of compliance. Social influence is an external factor with respect to warnings in that it is not part of the warning design.

Other factors that influence motivation to comply with a warning are time stress (Wogalter et al., 1998a) and mental workload (Wogalter and Usher, 1999). In high stress and high workload situations, competing activities distribute away some of the cognitive resources available for processing warning information and carrying out compliance behavior.

3.4.5 Behavior

The last stage of the sequential process is to carry out the warning-directed safe behavior. Determining what people will do in the context of a warning is a very desirable measure of its effectiveness. Behavioral compliance research shows that warnings can change behavior (e.g., Laughery et al., 1994; Cox et al., 1997; Wogalter et al., 2001). The main issue in contemporary research is to determine the factors and conditions that underlie whether or not a warning will be effective in producing compliance. Silver and Braun (1999) have reviewed published research that has measured compliance with warnings under various conditions. Many researchers have used intentions to comply because of the difficulty in measuring behavior under conditions or circumstances that enable conclusions to be drawn. Wogalter and Dingus (1999) showed that indirect measures may also be useful where a residual outcome of the behavior is examined (e.g., whether a pair of protective gloves have been used, according to its stretch marks).

3.4.6 Summary and Benefits of C-HIP

The foregoing review of factors influencing warning effectiveness was organized around the C-HIP model. This model divides the processing of

warning information into separate stages that must be completed successfully for compliance behavior to occur. A bottleneck at any given stage can inhibit processing at subsequent stages. Table 1 summarizes some of factors that influence the processing at each stage.

The basic C-HIP model can be a valuable tool in developing and evaluating warnings. Identifying potential processing bottlenecks can be useful in determining why a warning may or may not be successful. The model, in conjunction with empirical data obtained in various types of testing, can identify specific deficiencies in the warning system. Suppose that a manufacturer finds that a critical warning on their product label is not working to prevent accidents. The first reaction to solving the compliance problem might be to increase the size of the sign so that more people are likely to see it. But noticing the sign (the attention switch stage) might not be the problem. Potentially, user testing could show that all users report having seen the warning (attention switch stage), having read the warning (attention maintenance stage), having understood the warning (comprehension and memory stage), and having believed the message (the beliefs and attitudes stage). Thus, the problem with the manufacturer's warning in this case is likely to be at the motivation stage—users may not be complying because they believe the cost of complying with the warning (e.g., wearing uncomfortable personal protection equipment) outweighs the perceived belief about getting injured by not wearing the equipment. By using the model as an investigative tool, one can determine the specific causes of a warning's failure and not waste resources trying to fix the wrong aspect of the warning design.

For the practitioner, the model has utility in determining the adequacy and potential effectiveness of a warning. To the extent that a warning fails to meet various design criteria, the model can be a basis for judging adequacy. The lack of signal words, color, and pictorials or a poor location can be a basis for judging its adequacy regarding attention. A high reading level, the use of technical terminology, or the omission of critical information may be the basis of a warning's comprehension inadequacy. Failure to provide explicit consequences information in circumstances where the outcome of noncompliance may be catastrophic is inconsistent with adequacy criteria regarding motivation. Considerations such as these can be useful in formulating opinions regarding why a warning was not successful.

3.4.7 Demographic Factors

The sections above have provided a review of major concepts and findings organized on the basis of the C-HIP model. There are also relevant demographic characteristics of receivers. Receivers differ, and such differences must be considered in warning design. Laughery and Brelsford (1991) discussed a number of relevant dimensions along which intended receivers may differ. Several such factors have already been discussed, including experience and competence.

A number of studies have shown that gender and age may be related to how people respond to warnings. With regard to gender, results suggest a tendency for women to be more likely than men to look for and read warnings (Godfrey et al., 1983; LaRue and Cohen, 1987; Young et al., 1989). Similarly, some research results show that women are more likely to comply with warnings (Viscusi et al., 1986; Goldhaber and deTurck, 1988; Desaulniers, 1987). However, many other studies either do not report or do not find a gender difference.

Although results regarding age are mixed, there is a trend that people older than 40 are more likely to take precautions in response to warnings (Desaulniers, 1987). On the other hand, some research (Wogalter et al., 1999d; Wogalter and Vigilante, 2003) has shown that older adults have more difficulty reading small print on product labels than do younger adults. Other research (Easterby and Hakiel, 1981; Collins and Lerner, 1982; Ringseis and Caird, 1995) has shown that older subjects had lower levels of comprehension than that of younger adults for safety signs involving pictorials. Results such as these suggest that older people may be more influenced by warnings, but legibility and comprehension need to be considered.

Other potentially important demographics include locus of control (Laux and Brelsford, 1989; Donner, 1991) and self-efficacy (Lust et al., 1993). Persons who believe that they can control their destiny and/or who are less confident in a situation or task are more likely to read available warnings than persons who believe that fate controls their lives and/or who are more confident in a situation or task. When designing warnings for the general population, it may not be possible to address all of the needs of different people with a single warning; thus, a multimethod systems approach may be needed to meet the needs of the varying target audience.

4 DESIGNING FOR APPLICATION

It is important to design warning systems that will maximize their effectiveness. In this section we consider basic guidelines and principles to assist in the design and production of warnings.

4.1 Standards

A starting point in designing warnings is to consider guidelines such as the American National Standards Institute's Z535 (ANSI, 2002). This five-part series includes descriptions of safety colors, signs, symbols, labels, and tags. According to these guidelines, printed warnings should possess four textual components: (1) a signal word panel such as DANGER, WARNING, or CAUTION (with corresponding red, orange, or yellow color) and an alert symbol (triangle enclosing an exclamation mark) to attract attention to the warning and connote levels of hazard, (2) a hazard statement that describes the nature of the hazard briefly, (3) a description of the possible consequences associated with noncompliance, and (4) instructions for how to avoid the hazard. Research indicates that each of these four components benefit warning efficacy. There may

be exceptions when one (or more) of the component information items is clear or redundant from the other statements (Wogalter et al., 1987; Young et al., 1995) or from the presence of a pictorial symbol. Pictorial symbols can provide information on the hazard, consequences, or appropriate (or inappropriate) behavior and so can be used in lieu of some of the component text. The symbols should meet certain comprehension criteria to be acceptable for use as a warning by itself. Both the ANSI (2002) Z535.3 and ISO (2001) 9186 symbol standards provide guidelines and methods to assess symbol comprehension.

4.2 Potential Warning Components

Use of standards and guidelines only may not always produce an effective warning. In Table 2 we present a checklist of factors that should be considered in designing warnings. These factors are based not only on standards and guidelines but also on empirical research. Although not an exhaustive list, the table contains a set of factors that the warning literature indicates should be considered in warning design. Thus, one means of assessing a warning's effectiveness is simply to determine the extent to which the design meets appropriate criteria, such as those given in Table 2. With respect to attention, if no signal word is used, no color is employed, the print is small, the message is embedded in other types of information, and so on, then the effectiveness of the warning may be questioned. With respect to comprehension, if the reading level is high, technical language is used, or the statements are vague and not explicit, the warning may not be interpreted as intended.

Implementation of specific factors may also depend on situational-specific considerations such as target audience knowledge and/or characteristics of the product. For example, not all of the textual components in the table are necessary if members of the target audience are aware of the procedures needed to avoid injury at the appropriate time.

4.3 Principles

In addition to the factors in Table 2, there are other principles or guidelines that should be kept in mind when designing warnings or warning systems. These principles are described in the following sections.

4.3.1 Principle 1: Be Brief and Complete

As a general rule, warnings should be as brief as possible. Two separate statements should not be included if one will do, such as in the slippery floor example cited earlier. Longer warnings or those with nonessential information are less likely to be read, and they may be more difficult to understand. Obviously, this criterion should not be interpreted as a license to omit important information. The brevity criterion conflicts to some extent with the explicitness criterion. Being explicit about every hazard could result in very long warnings. A way to find a "happy medium" between brevity and completeness is discussed in Section 4.3.2.

Table 2 Warning Design Guidelines

Warning Component	Design Guidelines
Signal words	<p>DANGER — Indicates immediately hazardous situation that will result in death or serious injury if not avoided; use only in extreme situations. Use white print on a red background (ANSI Z535).</p> <p>WARNING — Indicates a potentially hazardous situation that may result in death or serious injury if not avoided. Use black print on an orange background.</p> <p>CAUTION — Indicates a potentially hazardous situation that may result in minor or moderate injury. Use black print on a yellow background.</p> <p>NOTICE — Indicates important nonhazard information. Use white print on a blue background. Although not in ANSI Z535, the term DEADLY connotes higher levels of hazard than DANGER. On the left side of the signal word is the alert symbol (triangle surrounding an exclamation mark).</p>
Format	<p>Text should be high contrast, preferably black print on white or yellow background, or vice versa.</p> <p>Left-justify text.</p> <p>Consistently position component elements.</p> <p>Orient messages to read from left to right.</p> <p>Each statement starts on its own line.</p> <p>Use white space or bullet points to separate statements or sets of statements.</p> <p>Give priority to the most important warning statements (e.g., position at the top).</p>
Wording	<p>Use as little text as necessary to convey the message clearly.</p> <p>Give information about the hazard, instructions on how to avoid the hazard, and consequences of failing to comply.</p> <p>Be explicit. Tell exactly what the hazard is, what the consequences are, what to do or not do.</p> <p>Use short statements rather than long, complicated sentences.</p> <p>Use concrete rather than abstract wording.</p> <p>Use short, familiar words.</p> <p>Use active rather than passive voice.</p> <p>Remove unnecessary connector words (e.g. prepositions, articles).</p> <p>Avoid using words or statements that might have multiple interpretations.</p> <p>Avoid using abbreviations unless they have been tested on the user population.</p> <p>Use multiple languages when necessary.</p>
Pictorial symbols	<p>When used alone, symbols should have at least 85% comprehension scores, with no more than 5% critical confusions (opposite or very wrong answers).</p> <p>Pictorials not passing a comprehension test should be accompanied by words, but critical confusions should still be avoided.</p> <p>Use bold shapes. Avoid including irrelevant details.</p> <p>Prohibition (circle slash) should not obscure critical elements of symbol.</p> <p>Should be legible under degraded conditions (e.g., distance, size, abrasion).</p>
Font	<p>Text should be legible enough to be seen by the intended audience and expected viewing distance.</p> <p>Use mixed-case letters. Avoid using all caps except for signal words or for specific emphasis.</p> <p>Use sans-serif fonts (Arial, Helvetica, etc.) for signal words and larger text.</p> <p>Use serif (Times, Times New Roman, etc.) fonts for smaller text.</p> <p>Use plain, familiar, nonfancy font.</p>
Other	<p>Locate/position so presentation is where it will be seen or heard.</p> <p>Test to assure that message fulfills C-HIP stages in Table 1.</p>

A concept related to completeness is overwarning. The term *overwarning* is sometimes used to label the extent to which our world is filled with warnings. The negative is that people may not attend to them or may become highly selective, attending only to some. The notion is that if warnings were to be put on everything, people would tune them out. Although this notion has face validity, there has been few empirical data assessing the limits implied. Nevertheless, overwarning may be a valid concern, and unnecessary warnings should be avoided.

Prioritization, discussed in the next section, is a useful approach in dealing with lengthier warnings for products and equipment that have multiple hazards.

4.3.2 Principle 2: Prioritize

Prioritization concerns what hazards to warn about and emphasize when multiple hazards exist. How are priorities defined in deciding what to include or delete, how to sequence items, or how much relative emphasis to give them? The criteria overlap the rules about

what and when to warn. According to Vigilante and Wogalter (1997a, b), considerations include:

1. *Likelihood.* The more likely it is that an undesirable event will occur, the greater the priority that it should be warned.

2. *Severity.* The more severe the potential consequences of a hazard, the greater the priority that it should be warned. If a chemical product poses a skin contact hazard, a higher priority would be given to a severe chemical burn consequence than if it were a minor rash.

3. *Known (or not known) to target population.* If the hazard is already known and understood or if it is open and obvious, warnings may not be needed (except as a possible reminder).

4. *Importance.* Is it important for people to know? In most cases, people want the opportunity to know about risks. Some hazards may be more important to people than others.

5. *Practicality.* There are occasions when limited space (a small label) or limited time (a television commercial) does not permit all hazards to be addressed in a single component of the warning system and still have a readable label.

As a general rule, unknown and important hazards leading to more severe consequences and/or those more likely to occur should have higher priority than less severe or less likely hazards. Higher-priority warnings should be placed first on the product label, and if not practical to place them all there, the lower-priority ones might go on other warning system components, such as package inserts or manuals.

4.3.3 Principle 3: Know the Receiver

Gather information and data about relevant receiver characteristics. This task may require time, effort, and money; but without it, the warning designer and ultimately the receiver will be at a serious disadvantage.

4.3.4 Principle 4: Design for a Low-End Receiver

When there is variability in the target population, which is almost always the case (especially when the audience is the general public), design for the low-end extreme. Safety communications should not be written at the level of the average or median percentile person in the target audience. Such warnings will present comprehension problems for people at lower competence, experience, and knowledge levels.

4.3.5 Principle 5: Employ a Warning System

When the target audience consists of subgroups that differ on relevant dimensions, or when they may be involved under different conditions, consider employing a warning system that includes different components. Do not assume that everything will be accomplished with a single warning.

4.3.6 Principle 6: Design for Durability

Warnings should be designed to last as long as needed. There are circumstances in which durability is typically not a problem. A product off the shelf of a drugstore that will be consumed immediately and completely is an example. On the other hand, products with a long life, such as cars and lawn mowers, may present a challenge. Similarly, situations where warnings are exposed to weather, such as on construction sites, or to extensive handling, such as on some containers, may pose durability problems.

4.3.7 Principle 7: Test the Warning

In addition to considering design criteria, it is frequently necessary to carry out some sort of testing to evaluate a particular warning or several prototype warnings. This approach may entail using small groups of people to give ideas for improvement and/or formal assessments involving larger numbers of people giving independent evaluations. Of course, the sample should be representative of the target audience.

To assess attention, a warning could be placed on a product and people could be asked to carry out a relevant task using the product to determine if they look at or notice it. Regarding comprehension, conducting studies to assess the extent to which a warning is understood probably has one of the best cost-benefit ratios of any procedure in the warnings design process. Relative to behavioral studies, comprehension can be assessed easily, quickly, and at low cost. Well-established methodologies involving memory tests, open-ended response tests, interviews, and so on, are applicable. Such studies can be exceptionally valuable in determining what information in the warning was or was not understood as well as what might be done in the way of redesign to increase the level of comprehension. Studies can also be carried out to determine the extent to which members of the target audience accept the warning information as true and, where appropriate, believe it to be applicable to them (beliefs and attitudes). Negative results on these dimensions would indicate that the warning lacks sufficient persuasiveness. Motivation can be assessed by obtaining measures of compliance intentions. Although such intention measures will generally reflect higher levels than will actual compliance, they can be useful for determining whether or not the warning is likely to be effective as well as for comparing warnings to determine which would probably be more effective.

Although behavioral compliance studies are generally difficult to execute, in situations where negative consequences of an ineffective warning are high, the effort may be warranted. Sometimes behavioral intentions are measured as a proxy because of the relative ease in collecting such data and/or the difficulty (including ethical considerations) in collecting behavioral data.

Studies carried out to evaluate the potential effectiveness of a warning must, of course, incorporate appropriate principles of research design. The selection of subjects to be representative of the target population,

avoiding confounding by extraneous variables, and guarding against contamination by expected outcomes are a few of the more salient factors that must be considered. For a more complete discussion of approaches to evaluating warning effectiveness, see Frantz et al. (1999), Wogalter and Dingus (1999), Wogalter et al. (1999c), and Young and Lovvoll (1999).

5 SUMMARY AND CONCLUSIONS

Warning design and effectiveness are comprised of many factors and considerations. In this chapter we have presented an overview of the current status of issues, including research, guidelines, and criteria for designing warnings. Approaches to dealing with environmental or product hazards are generally prioritized such that one first tries to solve the problem by design, then by guarding, then by warning. Thus, in the domain of safety, warnings are viewed as a third but important line of defense.

Warnings can properly be viewed as communications, whose purposes include informing and influencing the behavior of people. Warnings are not simply signs or labels. They can include a variety of media through which various types of information get communicated to a broad spectrum of people. The use of various media or channels and an understanding of the characteristics of the receivers or target audiences to whom warnings are directed are important in the design of effective warnings. The concept of a warning system with multiple components or channels for communication to a variety of receivers is central in this regard.

The design of warnings can and should be viewed as an integral part of systems design. Too often, it is carried out after the environment or product design is essentially completed, a kind of afterthought phenomenon. Importantly, warnings cannot and should not be expected to serve as a cure for bad design.

In this chapter we have covered the C-HIP model that included several processing stages based on communication theory and human information-processing theory. As part of this discussion, relevant factors influential at each stage were presented. In addition, guidelines and principles for warning design in application were presented.

Determining whether or not a warning will influence behavior is usually a difficult assignment. In addition to the ethical problems of exposing people to hazards, actual field studies testing warnings are likely to be time consuming and costly. Certainly, where feasible, such studies are desirable. Also, although laboratory or other controlled simulations of warning situations can be useful in assessing behavioral effects, such approaches leave open questions of generalizability. Studies that examine the effects of warnings on attention, comprehension, beliefs and attitudes, and motivation to comply can be valuable as part of the process of designing and assessing warnings. Such studies can help in isolating why a warning is not effective. A behavioral study which shows that people do not comply with a warning may not tell us if it failed because it was not noticed, or because it was not

understood, or because it was not believed, or because it was unable to motivate. Studies employing attention, comprehension, risk perception, or behavioral intention measures can provide information that, in turn, can be useful in developing alternative warning designs that are effective (e.g., Wogalter and Young, 1994).

The issue of warning effectiveness has received a great deal of attention in recent years, especially the means by which effectiveness is assessed. Several criteria can be employed in assessing warnings, including whether they capture and maintain attention, are understood, are consistent with or capable of modifying beliefs and attitudes, motivate people to comply, and result in people behaving safely. The assessment of warning effectiveness employing approaches such as these can and should be part of the warning design process.

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