Wogalter, M.S., Laughery, K. R., & Mayhorn, C. B. (2012). Warnings and hazard communications (Chap. 29). In G. Salvendy (eds.), *Handbook of Human Factors / Ergonomics* (4th ed.). New York: Wiley.

CHAPTER 29

WARNINGS AND HAZARD COMMUNICATIONS

Michael S. Wogalter
Psychology Department, North Carolina State University
Raleigh, North Carolina

Kenneth R. Laughery, Sr.
Psychology Department, Rice University
Houston, Texas

Christopher B. Mayhorn
Psychology Department, North Carolina State University
Raleigh, North Carolina

1 INTRODUCTION

Warnings are safety communications that are used to inform people about hazards and to provide instructions so as to avoid or minimize undesirable consequences such as injury of death. Warnings are used in a variety of contexts to address environmental and product-related hazards.

In the United States, interest in warnings is also associated with 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 the warning is absent or defective, then the product is defective (see, e.g., 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.

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

2 BACKGROUND

In this section several terms will be defined and the role of warnings in the broader context of hazard control will be discussed.

2.1 Definitions

It is important to establish a few definitions for terms that will be used in this chapter, particularly the concepts of hazard and danger. These terms are sometimes used in different ways with different meanings; hence, we want to be clear as to their meaning in this context.

Hazard is defined as a set of circumstances that can result in injury, illness, or property damage. Such circumstances may include characteristics of the environment, of equipment, and of a task someone is performing. From a human factors perspective, it is important to note that circumstances also include characteristics of the people involved. These people characteristics encompass abilities, limitations, and knowledge.

Danger is a term that is used in a variety of ways. In this chapter it is viewed as the product of hazard and likelihood; that is, if one has quantified values of hazard and likelihood, multiplying these quantities would give a value for danger. Note that an implication of this definition is that if either value is zero, there is no danger. If the hazard and its consequence are serious but will not occur, there is no danger. Similarly, if the probability of an event occurring is high but there will be no resulting undesirable consequences, there is no danger. Note, however, people commonly use the words hazard and danger interchangeably.

2.2 Hierarchy of Hazard Control

In the field of safety there is a concept of hazard control that includes the notion of a hierarchy (Sanders and McCormick, 1993). This hierarchy defines a sequence of approaches to dealing with hazards in order of preference. The sequence is (1) design it out, (2) guard against it, and (3) warn about it. The notion of a design solution is that the first preference is to eliminate the hazard through alternative designs. If a nonflammable solution can be used effectively for a cleaning task, then such a solution is preferable to wearing protective equipment or warning about avoiding an ignition source due to flammability. Of course, often it is not possible to eliminate hazards. Guarding, whether physical or procedural, is a second line of defense and has as its purpose preventing contact between people and the hazard. Barriers and protective equipment are examples of physical barriers while designing tasks in such a way as to keep people out of a hazard zone is an example of a procedural guard. However, like alternative designs, guarding is not always a feasible solution, and the third line of defense is warning. Warnings are third in the priority sequence because influencing behavior is sometimes difficult and seldom foolproof. There is another implication of this priority scheme; namely, warnings are not a substitute for good design or adequate guarding. Indeed, warnings are properly viewed as a supplement, not a substitute, to other approaches to safety (Lehto and Salvendy, 1995).

In addition to the above three-part hierarchy, there are other approaches that may be effective in dealing with hazards (see, e.g., Laughery and Wogalter, 2011). Generally, they fall into the same category as warnings in that they are means of influencing the behavior of people. Training and personnel selection are examples. Another approach that includes elements similar to procedural guarding and warnings is supervisory control. These latter approaches are particularly applicable to hazards in the context of employment and job performance.

3 WARNINGS

In this section the purpose(s) of warnings and some general criteria for warnings are discussed.

3.1 Purpose of Warnings

The purpose of warnings can be explained at several levels. Most generally, warnings are intended to improve safety, that is, to decrease accidents or incidents that result in injury, illness, or property damage. At another level, warnings are intended to influence or modify people's behavior in ways that will improve safety. At still another level, warnings are intended to provide information that enables people to understand hazards, consequences, and appropriate behaviors that in turn enable them to make informed decisions. This latter point places warnings as a type of communication.

There are two additional points associated with the purposes of warnings. First, warnings are sometimes used as a means of shifting or assigning responsibility for safety to people in the system, the product user, the worker, and so on, in situations where hazards cannot be designed out or adequately guarded. This point 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. Whether responsibility has been shifted depends at least in part on the effectiveness of the communications. The second point regarding warnings' communication purpose concerns an issue that has received little attention in the technical literature, namely, people's right to know. This notion makes the point 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. This aspect of warnings relates to personal, societal, and legal concerns.

3.2 General Criteria for Warnings

The most important general criterion for warnings is that their design should be viewed as an integral part of the overall system design process. Frantz et al. (1999) address this issue in a chapter on developing product warnings. While safety warnings are a third line of defense behind design and guarding, they should not be considered for the first time after the design (including guards) of the environment or product has already been set and established. Too many warnings are developed at this late stage of design, as an afterthought, and their quality and effectiveness often reflect it. Further, warnings based on unrealistic and untested assumptions or expectations about the target audience are destined to be inadequate.

3.2.1 When/What to Warn?

There are several principles or rules that guide when a warning should be used. They include:

1. A significant hazard exists.
2. The hazard, consequences, and appropriate safe modes of behavior are not known by the people exposed to the hazard.
3. The hazards are not open and obvious; that is, the appearance and function of the environment or product do not convey them.
4. A reminder is needed to assure awareness of the hazard at the proper time. This concern is especially important in situations of high task loading or potential distractions.

3.2.2 Who to Warn

The general principle regarding who should be warned is that it should include everyone who may be exposed to the hazard and everyone who may be able to do something about it. There are occasions when people in the latter category may not themselves be exposed to the hazard. An example would be the industrial toxicologist who receives warning information regarding a product to be used by employees and who then defines job procedures and/or protective equipment to be employed in handling the material. The physician who prescribes medications with side-effect hazards is another example.

There are, of course, situations and products where the target audience is the general public and that includes nearly everyone. Hazards in the public environment or products on the shelf of a drugstore or hardware store are examples. Other warnings may be directed to a very specific audience. Warnings about the risk of birth defects associated with taking a prescription medication would be directed primarily to women of child-bearing age; although others such as spouses or parents might also receive the warning (Mayhorn and Goldsworthy, 2007). Likewise, as noted above, health care professionals such as physicians or pharmacists should receive the warnings regarding potential birth defects when treating patients who are or may become pregnant. If warnings are to be effective, the characteristics of the target audience should be taken into account.

4 COMMUNICATION-HUMAN INFORMATION PROCESSING (C-HIP) MODEL

In this section a theoretical context is presented that will serve as an organizing framework or model for reviewing some of the major concepts and findings regarding factors that influence warning effectiveness. Specifically, a C-HIP model is described (Wogalter, 2006a). To place this model in context, a few general comments about communications and human information processing are in order.

Communications Warnings are a form of safety communications. Communication models have been around for most of the last 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, and so on. 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 successfully conveyed.

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

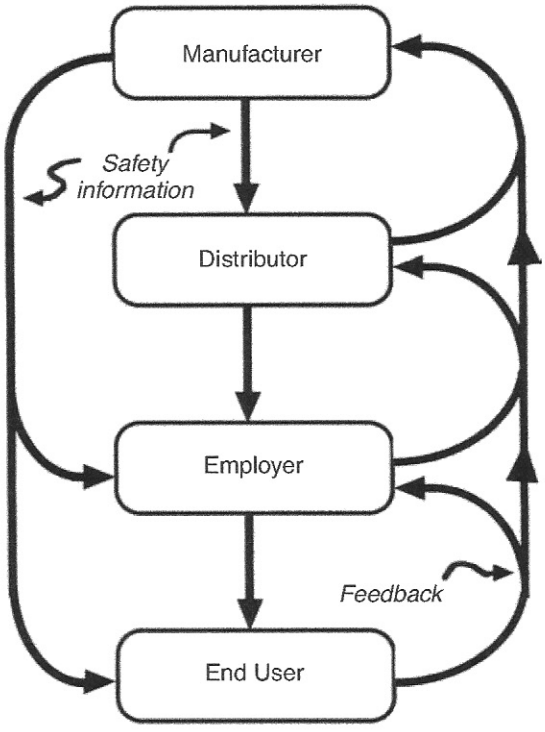

Figure 1 Distribution of safety information and feedback.

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 different forms. One example includes safety rules that an employer sets to govern the behavior of employees. Thus, warnings or warning systems may be much more complex than just a sign or label. The concepts of warning systems and indirect warnings are 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, memory, and decision making. Since the 1960s, much of the theoretical work has been described in terms of stages of processing. Numerous models have been developed and tested. In the next section, C-HIP is described as a model that incorporates some basic stages of mental processing.

C-HIP Model The C-HIP model (Wogalter, 2006a) depicted in Figure 2 is a framework for showing stages of information flow from a source to a receiver who in turn may cognitively process the information to subsequently produce compliance behavior. One of the main benefits of the C-HIP model is that it serves as a guiding framework for organizing diverse findings in the warning research literature.

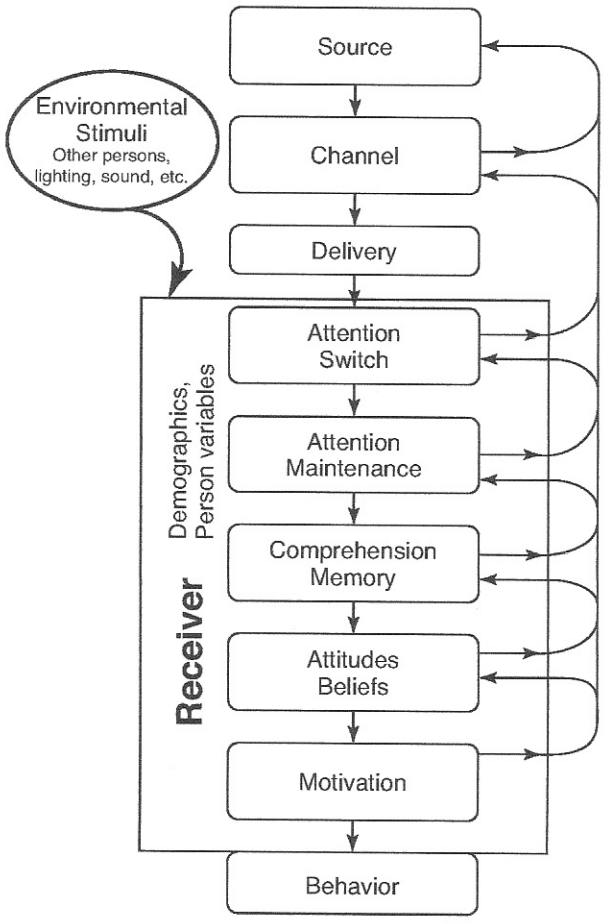

Figure 2 The C-HIP model.

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. If all of the stages are successful, the process ends in behavior (compliance). While the processing of the warning might not make it 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" because it produces better understanding and can potentially lead to better, more informed decisions. However, it is ineffective in the sense that it may not curtail certain unsafe behaviors.

The C-HIP model can be particularly useful in 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 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 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 might 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, we describe each stage of the C-HIP model and 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 presented here is somewhat different than those presented in Wogalter et al. (1999b) and Wogalter and Laughery (2005). Over the years, the body of research has grown to the extent that it now requires fairly substantial books to describe and summarize the literature (e.g., Wogalter et al. 1999b; Wogalter 2006b). This chapter gives an overview of research findings relevant to each stage of C-HIP. In both Wogalter et al. (1999b) and Wogalter (2006b) there are individual detailed chapters on most of the model's stages. The model has evolved over time. The model that predated the C-HIP (Wogalter and Laughery 1996) simply presented some of the main human information processing stages (i.e., in the receiver section), in other words, only the second section of stages of the eventual C-HIP model. The Wogalter et al. (1999b) version of C-HIP added the first section from communication theory (source and channel). The most recent model from Wogalter (2006a) (shown in Figure 2) is different in four ways from Wogalter et al.'s (1999b) C-HIP model. First, in the current model the attention stage is split into two separate stages, attention switch and attention maintenance. The reason for the split is that these two stages are different and are affected by different variables. The second major difference in the models is that there is now the stage of delivery (Williamson 2006). Delivery refers to the point of warning reception where information is provided to the receiver via one or more channels. The third change in the current model is an explicit reference to the influence of other environmental stimuli. Environmental influences are aspects other than the warning itself that could affect how the warning is processed. They are extrinsic to the warning. Environmental influences can include other information on the product label, the product itself, other people's involvement, other warnings, and other aspects in the environment, including illumination and background noise (Vredenburgh and Helmick-Rich, 2006). The fourth major change from the Wogalter et al. (1999b) C-HIP model to the current model is greater emphasis on the receiver's personal characteristics (e.g., demographics) and task involvement (Smith-Jackson, 2006b; Smith-Jackson and Wogalter, 2007; Wogalter and Usher, 1999). Both the third and the fourth changes serve to emphasize how context (outside the person and warning and internal aspects of the target person) can influence the processing of warning content.

Table 1 shows a summary of some of the primary considerations associated with successful processing at each stage.

4.1 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., 1999c). Information from a reliable, expert source [e.g., the Surgeon General, the U.S. Food and Drug Administration (FDA)] is given greater credibility, particularly when the expertise is relevant (e.g., the American Medical Association and the FDA for a health-related warning) (Wogalter et al., 1999c). Indeed, Internet users are more likely to believe facts they encounter on websites that have domain suffixes such as .edu and .gov than .com because they are from educational- or governmental-related sources as opposed to for-profit companies (Wogalter and Mayhorn, 2008). An important aspect that will be 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 outcomes of hazard analyses that determine foreseeable ways injuries could occur. Assuming that the product or environment has been determined to need a warning, one or more communications channels must be used to reach the receiver.

4.2 Channel

The channel is the medium in which information is transmitted from the source to one or more receivers. In the past, most warnings have been presented on product labels, on posters, or in brochures. These traditional methods of "static" display will be enhanced through the use of technology-based dynamic displays in the future. Future warning systems will likely have properties that are different and better than those inherent in traditional static warnings [see Wogalter and Mayhorn (2005a) for a review]. For example, computers and sensors can be used to process information to enable warnings to be appropriately tailored to the situation and characteristics of the target user (Wogalter and Mayhorn, 2005a). Whether communicated via traditional static or technology-based dynamic media, warnings are often 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 (LP) or natural gas can make use of the olfactory sense, and a pilot's control stick that is designed to vibrate when the aircraft begins a potentially dangerous stall makes use of the tactile, haptic, and kinesthetic senses.

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) versus 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 usually better for attracting attention (a stage described below). However, auditory presentation can be less effective than

Table 1 Methods and Influences of C-HIP Stages

C-Hip Stage	Methods and Influences
Source	• Determines that hazard is not designed out or guarded • Credible, expert
Channel	Sensory modality 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. Media Print (label, manual, brochure, magazine advertisement sign) Voice (radio, live), Video (TV), Internet
Delivery	Make sure message gets to target audience(s). Did it arrive to one or more of the receiver's sensory modalities?
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 (e.g., using distinctive color, motion/movement) Visual: high contrast, large Presence of pictorial symbols and other graphics can aid noticeability. Auditory: louder and distinguishable from surround Present when and where needed (placed proximal in time and space) Avoid habituation by changing stimulus. Measurement: recording eye and head movements
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 Measurement: duration of looking/listening and subsequent recall and recognition
Comprehension and memory	Enables informed judgment Understandable message that provides necessary and complete 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 (low literates or unskilled in language). At subsequent exposures, warning can cue or remind user of information. Comprehension testing needed to determine whether warning communicates intended/needed information Measurement: Testing understanding of intended message after exposure: Does it communicate all of the intended necessary information?
Beliefs/attitudes	Perceived hazard and familiarity are beliefs that affect warning processing. Persuasive argument and prominent warning design are needed when beliefs are discrepant with truth so as to appropriately alter those beliefs. Can have influence receiver's earlier stages Measurement: Determine beliefs (pre- and post-).
Motivation	Energizes person to carry out next stage (behavior) Perceived low cost (time, effort, money) facilitates compliance. Perceived high cost of compliance increases likelihood of noncompliance. Motivation benefited by explicitness and perceived injury severity. Affected by social influence, time stress, mental workload Measurement: Ratings of willingness to carry out the directed behavior
Behavior	Carrying out safe behavior that does not result in injury or property damage Measurement: Behavioral compliance

visual presentation, particularly for processing lengthy, complex messages because (a) of its primary temporal/sequential nature, (b) its processing speed is slower, and (c) 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).

Multiple Methods and Redundancy Research has generally found that presenting warnings in two modalities is better than one modality. Thus, a warning is better if the words are shown on a visual display while at the same time the same information is given orally. This provides redundancy. Together they can be beneficial as it provides a way for persons who may be occupied on a task involving attention to one or the other modality to be alerted by the warning. If an individual is not watching the display, people can still hear it. Or, if an individual is listening to something else (or is wearing hearing protection), they could potentially see the message on the visual display. Also, if the individual is blind or deaf, the information is available in the other modality. A similar concept for media is described below.

Warning System The idea that a warning is only a sign or a portion of a label is too narrow a view of how 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 a pharmaceutical product such as a prescription allergy medication may consist of several components: a verbal warning from a physician, 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 and radio advertisements that specifically target consumers. In the United States, direct-to-consumer (DTC) advertisements about prescription pharmaceuticals usually include warnings about side effects and contraindications. Due to the brevity of most broadcast commercials, these DTC ads frequently direct people to other sources of information such as manufacturer websites or a toll-free telephone number (Goldsworthy and Mayhorn, 2010; Kim et al., 2010; Vigilante et al., 2007). Likewise, 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 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 via mail or the Internet. Yet another example would be warnings for a solvent used in a work environment for cleaning parts. Here the components might include warnings printed on labels of the container, printed flyers that accompany the product, and material safety data sheets (MSDSs) provided to employers. They might also include statements in advertisements about the product and verbal statements from the salesperson to a purchasing agent.

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 above solvent example, the label on the product container may be intended for everyone associated with the use of the product, including the end user, while the information in the MSDS may be directed more to fire personnel or to an industrial toxicologist or safety engineer working for the employer (Smith-Jackson and Wogalter, 2007).

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 directly exposed to the warning. That is, he or she directly reads or hears the warning. But warnings can also accomplish their purposes when delivered indirectly (Wogalter and Feng, 2010). One example gleaned from research by Tam and Greenfield (2010) suggests that the indirect effects associated with alcoholic-beverage warnings may explain gender differences in the likelihood to intervene to prevent others from driving while intoxicated. The employer or physician who reads warnings and then verbally communicates the information to employees or patients is also an 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 directly exposed to the warning.

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 farm workers 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 also other ways to increase surface area to print additional warning material, some of which are described later.

There are situations where we rely on indirect communications to transmit warning information. Employers and physicians are examples already noted; however, adults who have responsibility for the safety of children are another important category (Mayhorn et al., 2006). In the design of warning systems, empowering indirect warnings could enhance the spread of warning information to relevant targets.

4.3 Delivery

While 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). For example, without the manual, the user may not know what the correct and incorrect uses of the product are or what the maintenance schedule is, which could impact safety. Williamson (2006) describes issues associated with communicating warnings on the flash-fire hazard associated with burning plastic-based insulation. Although there are some warnings accompanying bulk lots of the insulation when shipped from the manufacturer/distributor to job sites and some technical warnings that 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. Likewise, prescription medications that are shared with others may not be seen in the original containers that include warnings regarding side effects (Goldsworthy et al., 2008b). The point here is that while 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.

4.4 Receiver

In this section the focus is 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 effectively communicate information and influence behavior, 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.

4.4.1 Attention

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

Attention Switch 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 where other stimuli are competing for attention.

For a warning to capture attention it must first be available to the recipient. As noted earlier, warning messages will not have direct effects if they are not received by the end user. Assuming 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. What is important is not just the size of the warning 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 available in a well-designed owner's manual or website. Wogalter et al. (1995) have shown such a procedure can sometimes be effective.

Color While there are some problems with the use of color such as color blindness, fading, and lack of contrast with certain other colors, good use of color can benefit warnings. Coloration can help a warning attract attention more effectively than a warning that is the same color as its surroundings, including other text around it (e.g., Laughery et al., 1993b). The ANSI(2006) Z535.2 and Z535.4 standard for signs and labels uses color in the signal word panel.

Pictorial Symbols Pictorial symbols and icons can be useful for attracting attention (Bzostek and Wogalter, 1999; Jaynes and Boles, 1990; Kalsher et al., 1996; Mayhorn et al., 2004b; Mayhorn and Goldsworthy, 2009; Young and Wogalter, 1990). A common icon used in warnings that can help attract attention is the alert icon (triangle enclosing an exclamation point) (Laughery et al., 1993a) that is found in the signal word panel in the ANSI 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 Rhoades, 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 similar warning embedded somewhere in the middle of a vehicle owner's manual. A verbal warning given two days ago before a farm worker 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 an out-of-view location, drastically reduces its likely effectiveness. In general, placement of warnings directly on a hazardous product is preferred (Wogalter et al., 1987). However, this cannot always be done given the product and the circumstances of use. 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 a hard drive installed inside a computer will not be seen if the user does not open the interior panel of the computer. People generally do not read owner's manuals of cars they rent; thus, unless warned some other way, such as on a dashboard placard or in a quick-tip chart, drivers will not be made aware of certain safety information. Manufacturers need to consider how their product may be used, so they can select proper locations for warnings. In general, warnings should be located near where they are needed both in proximal location and in time. Task analyses are likely to be beneficial here.

Warnings should preferably be placed before or above the instructions for use. Warnings should not be buried in the middle of other text or on a later page. Wogalter et al. (1987) showed 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 following them.

Sometimes practical considerations limit the available options. A small container for some over-the-counter medications may simply not have the space for all of the necessary warning information. Some options for addressing this problem are discussed later.

Formatting Another factor that can influence attention is formatting. Aesthetically pleasing warning text, with plenty of white space and coherent information groupings (Hartley, 1994), are more likely to attract and hold attention (Wogalter and Vigilante, 2003). If a warning contains a large amount of dense text, individuals may decide too much effort is required to read it and thus may decide to 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). Such efforts to combat habituation may be accomplished through the use of technology-based dynamic warnings where warning content and format can be changed as needed (Wogalter and Mayhorn, 2005a). For example, electronic highway safety signs that change to dynamically report on actual specific information about real-time traffic flow and the presence of construction, vehicular crash, or flooding ahead are probably much more effective in eliciting more informed and better decisions than a general static sign saying "Traffic Congestion Ahead." More about habituation will be described in a later section.

Other Environmental Stimuli Other stimuli in the environment may compete with the warning for attention capture. These stimuli may include the presence of other persons, various objects that comprise the context, and the tasks being performed. Thus, the warning must stand out from the background (i.e., be salient or conspicuous) to be more likely 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. Because safety considerations are not always on one's mind, warnings need to be prominent.

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 in capturing attention is largely a matter of salience. Auditory warnings should be louder and distinctively different from expected background noise. Auditory warnings are sometimes used in conjunction with visual warnings, with the auditory warning serving to call attention to the need to examine a visual warning with more specific information.

Sensor Technology In some instances, hazards or indications of hazards are outside the range of human sensory perception, leaving persons at risk unaware of the danger without some additional means of detection. One example is detecting carbon monoxide gas; it its pure form, it has no odor. Technology has enabled sensors capable of detecting the presence of carbon monoxide gas as well as other gases such as propane and natural gas. There are numerous other kinds of detection systems available that can "sense" a variety of indicators such as motion, temperature, and weight. These sensors can provide input into systems that could, in turn, provide a perceptible and informative warning.

Attention Maintenance Individuals 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 at 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 glare can negatively affect legibility.

Sanders and McCormick (1993) give data on 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. There is not much research to support a clear preference for certain fonts over others; the general recommendation is to use relatively plain, familiar fonts. It is sometimes recommended that a serif font, with embellishments in the lettering, such as Times Roman be used for small point sizes containing message text and sans serif font (plain fonts without embellishments) such as Helvetica be used in applications requiring larger point size headline-type text. The American National Standards Institute's (ANSI, 2006) Z535.2 and Z535.4 warning sign and label standard include a chart of print size and expected reading distances in good and degraded conditions.

Contrast and color are other considerations. 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 use a red warning on a largely red background.

Formatting Visual warnings formatted to be aesthetically pleasing are more likely to hold attention (and thus examined and the information extracted) than a single chunk of dense text (Vigilante and Wogalter, 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 bold bulleted lists are preferred to long, dense prose text (e.g., Desaulniers, 1987; Wogalter and Post, 1989). While aesthetically pleasing at a distance, full justification (straight alignment at both margins) is more difficult to read than "ragged right" justification (straight alignment only at the left margin) because the spacing between letters and words is consistent, thus aiding saccadic movement during reading.

Pictorial Symbols Interest is also facilitated by the presence of well-designed pictorial symbols. Further, research indicates people prefer warnings that have a pictorial symbol to warnings without one (Kalsher et al., 1996; Mayhorn and Goldsworthy, 2009; Young et al., 1995).

Auditory Simple nonverbal auditory warnings are often 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 usually used to access further information (Sanders and McCormick, 1993; Sorkin, 1987).

4.4.2 Comprehension

Warning comprehension concerns understanding its meaning. Some comprehension may derive from subjective understanding such as its hazard connotation given it appearance and presentation and some from the specific language and the symbols used. The processes involve people's existing memory and knowledge together with the warning and contextual stimulation.

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 (2006) Z535 and guidelines (e.g., FMC Corporation, 1985; Westinghouse Electric Corporation, 1981) 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 (not pictured) 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 property might occur, such as getting hands caught in operating

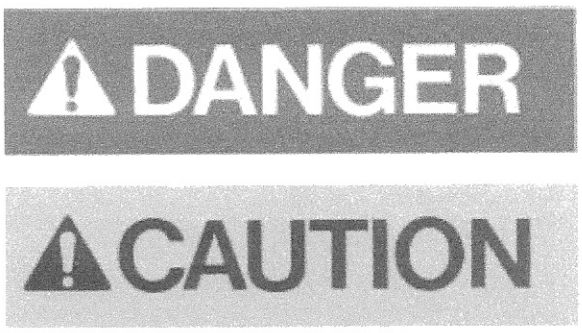

Figure 3 Examples of two signal word panels including alert symbol and color. Note that the DANGER panel is white print on red background and the CAUTION is black print on yellow background. Not shown is the WARNING panel, which is black print on orange background.

equipment. Research shows that lay persons 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 the ANSI, yet it might be considered for hazards that are significantly above those connoted by the term DANGER.

Different characteristics of sounds can lead to different hazard connotations. Higher frequency (higher pitch) and greater amplitude (louder), which have faster repetitions, are perceived as more urgent (Edworthy et al., 1991). Similar effects have been shown with verbal speech (Barzegar and Wogalter, 1998; Hellier et al., 2002; Hollander and Wogalter, 2000; Weedon et al., 2000).

In the ANSI warning's top panel, the signal words DANGER, WARNING, AND CAUTION are assigned to a paired color (red, orange, and yellow, respectively). This assignment is a method of redundancy, which is useful if one cannot read or cannot perceive the color. However, the colors for WARNING (with its color pair orange) and CAUTION (with its color pair yellow) are not readily distinguished with regard to hazard connotation. Nevertheless, DANGER (with its color pair red) is consistently judged as having a higher hazard connotation (as measured by ratings) than the other two signal word–color combinations (e.g., Chapanis, 1994; Mayhorn et al., 2004c).

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. A person who is illiterate would not be able to read the warning text.

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 at least easily 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 found on containers of solvents: "Avoid breathing fumes." This might be difficult to carry out for several reasons. One reason is difficulty in detecting fumes, particularly if one cannot see or smell them (e.g., if one has nasal congestion). A second reason pertains to behavior with respect to personal protection equipment. If a respirator with an independent air supply is not available, then avoidance may be difficult.

Three characteristics of receivers related to cognitive competence are important in warning design: technical knowledge, language knowledge, and reading skill. The communication of hazards associated with medications, chemicals, and mechanical devices is complex and technical in nature. If the target audience does not have the relevant technical competence needed to interpret the information, a warning concerning hazards in these domain is likely to be unsuccessful. The level of knowledge and understanding of the audience must be taken into account. This point will be 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 increasingly international, requirements for warnings to be directed to users of different languages will increase. Potential ways to deal with this problem include use of multiple languages and pictorials (Lim and Wogalter, 2003).

Reading skills and capabilities in the population vary from illiteracy to graduate-level skills. Yet, high reading levels such as a grade 12 (high school graduation level) are common in warnings that are also intended for individuals who have low-level reading skill. In general, the reading level of at least the most important parts of the warning should be as low as feasible. For general target audiences, the reading level might need to be in the fourth- to sixth-grade levels (education of children 10–12 years old). Clearly, some warnings may be directed at professionals such as licensed health care professionals who have some expected level of training and can therefore be more technical. The reading levels should be matched with the intended target audience. There are readability formulas 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 and are notorious for giving inaccurate estimates on comprehensibility. However, they could be useful in analyzing the text while trying to achieve a comprehensible warning. A discussion of reading level measures and their application to the design of instructions and warnings can be found in Duffy (1985).

An additional point on reading ability concerns illiteracy. Even in the richest countries of the world there are a substantial number of functional illiterates. There are estimates that over 16 million functionally illiterate adults exist in the U.S. population. Therefore, successfully communicating warnings may require more than simply keeping reading levels to a minimum. While simple solutions to this problem do not exist, well-designed pictorials, speech warnings, special training programs, and so on, may be important components of warning systems to accommodate these groups.

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 about potential safety problems. Example hazard statements are:

Toxic vapors
Slippery floor
High voltage (7200 volts)

A general principle is that the hazard should be spelled out clearly in a warning. The exceptions pertain to when the hazard is (a) generally known by the population, (b) known from previous experience, or (c) "open and obvious." (The latter two concepts will be described in more detail in a subsequent section). Other than these exceptions, hazard information is an important component of most warnings (Wogalter et al., 1987).

Consequences Consequences information concerns the nature of the injury, illness, or property damage that could result from the hazard. Hazard and consequence information is 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. Statements regarding these two elements are sometimes purposely sequenced in this way such as in "Toxic Vapor, Severe Lung Damage."

Sometimes, however, it is desirable to put consequences information near the beginning of the warning for the purposes of getting and holding the receiver's attention (Young et al., 1995). This is particularly true for severe consequences such as death, paralysis, and severe lung damage. So the appropriate sequence of statements is the opposite of that mentioned above, as in "Severe Lung Damage, Toxic Vapor."

There are also situations when the hazard information in a warning is presented and understood, where 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 "Wet 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. Nevertheless, the hazard statement could be improved with including "Slippery" instead of "Wet" so as to include consequences in with the statement. Although this is a simple example, it shows how consequence information can be included together with a hazard statement relatively easily without appearing superfluous.

An important reason why consequences information is needed is that warning recipients may not make the correct inference regarding injury, illness, or property damage outcomes with more complex hazards than a wet floor. Previous research with older adults indicates that people aged 65+ years often have difficulty comprehending warning content when inferences are required (Hancock et al., 2005). Thus, it is important in designing warnings to assess, if necessary, whether people correctly infer the consequences and, if not, then to reword or redesign the warning so it is more specific and informative.

The lack of specificity is a shortcoming in many warnings. They often fail to provide important 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). Also giving only general information frequently fails one of the main purposes of warnings — to give "informed consent" about risks. As will be discussed later, knowledge about severe consequences can motivate attention to and compliance with the warning message (see section on motivation).

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 separately. Figure 4 contains some example industrial safety symbols that convey hazard and consequence information. Pictorial warnings that illustrate both hazard and consequence information are preferred (Goldsworthy et al., 2008a; Mayhorn and Goldsworthy, 2007, 2009).

Instructions In addition to getting people's attention and telling them about the hazard and potential consequences, warnings should also instruct people about what to do or not do in order to stay safe and/or prevent property damage. Typically, but not always, instructions in a warning follow the hazard and consequence information. An example of an instructional statement is "Must Use Respirator Type 1234," which could be included in the context of hazard and consequence statements, as in "Severe Lung Damage, Toxic Vapors, Must Use Respirator Type 1234." The 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

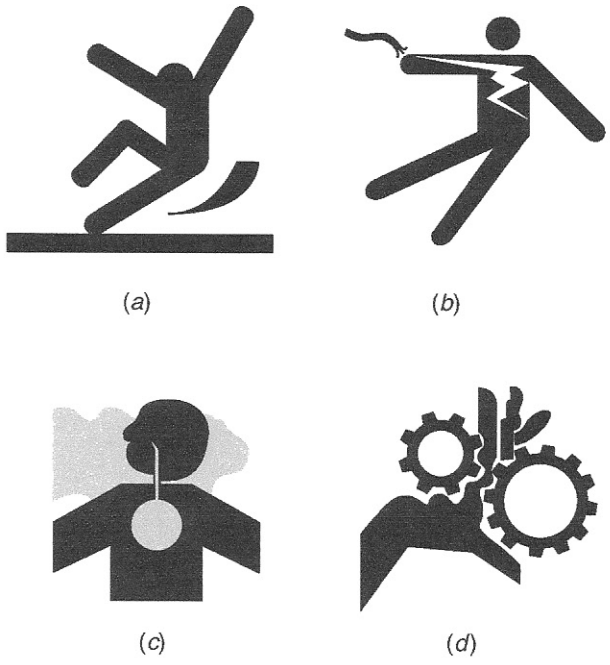

Figure 4 Examples of pictorials conveying hazard information: (*a*) slippery floor; (*b*) electrical shock; (*c*) toxic gas; (*d*) pinch point.

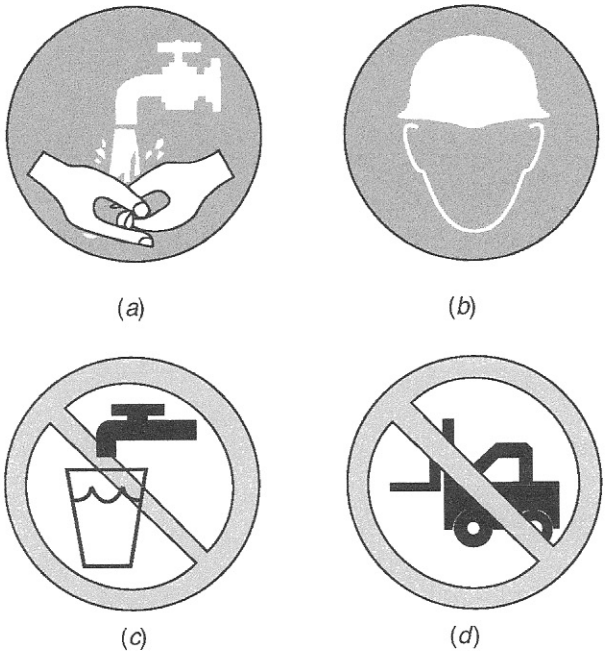

Figure 5 Examples of pictorials conveying instructions/directions information: (*a*) wash hands; (*b*) wear hard hat; (*c*) do not drink water; (*d*) no forklifts in area.

safety, while 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, then they can be viewed as part of a warning. In short, warnings include instructions, but not all instructions are parts of a warning.

Explicitness Previously, it was mentioned that specificity is generally preferred over generalities. An important design principle relevant to warning comprehension is explicitness (Laughery et al., 1993a; Laughery and Paige-Smith, 2006). 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 enough. However, sometimes, as stated earlier, technical details are not necessary and could be detrimental in certain instances. The following two examples of warnings, each with hazard, consequence, and instructional statements, are inadequate with regard to explicitness: (a) "Dangerous Environment, Health Hazard, Use Precautions" and (b) "Mechanical Hazard, Injury Possible, Exercise Care." Explicit alternatives might be (a) "Severe Lung Damage, Toxic Chlorine Vapor, Must Use Respirator-Type 123" and (b) "Pinch Point Hazard—Moving Rollers, Your Hand/Arm May Be Severely Crushed or Amputated, Do Not Operate without Guard X89 in Place."

Pictorial Symbols Pictorial symbols are used to communicate hazard-related information, often in conjunction with a printed text message. Guidelines such as ANSI (2006) Z535.3 and FMC Corporation (1985) place considerable emphasis on the use of safety symbols. Pictorials are particularly useful in helping to increase comprehension (Boersema and Zwaga, 1989; Collins, 1983; Dewar, 1999; Lerner and Collins, 1980; Laux et al., 1989; Wolff and Wogalter, 1993, 1998; Zwaga and Easterby, 1984). Well-designed symbols can be useful to low literates or to persons who do not use the regional language (Mayhorn and Goldsworthy, 2007, 2009). Well-designed pictorials can potentially cue large amounts of knowledge at a glance.

Clearly comprehension is a primary concern 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. Nowhere is this more apparent than the instance cited by Casey (1998) where hundreds of Kurdish farmers in Northern Iraq died when they consumed grain treated

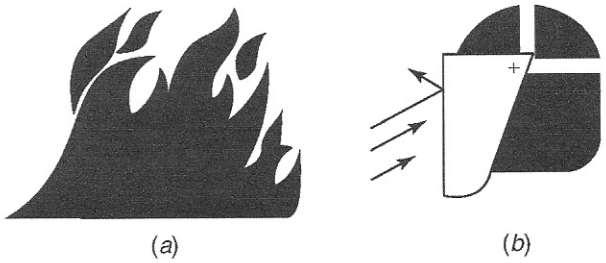

Figure 6 Examples of pictorials showing a direct representation: (*a*) raging fire and (*b*) wear eye shield.

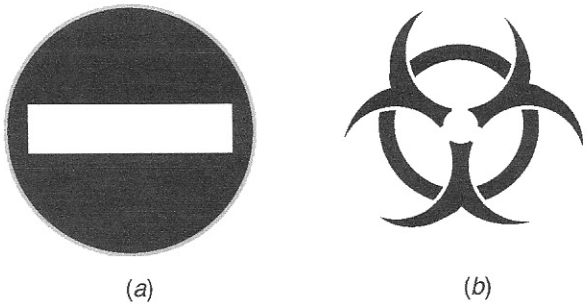

Figure 7 Examples of pictorials that can be recognized only after learning: (*a*) do not enter and (*b*) biohazard.

with alkyl mercury fungicide because they did not recognize the skull and crossbones symbol as meaning "poison." Reports following the incident suggest that the Kurd farmers believed the skull and crossbones symbol to be a piece of artwork associated with a corporate logo. This example clearly illustrates that cultural differences can also affect warning comprehension (Smith-Jackson and Wogalter, 2000). Other pictorials are completely abstract, such as the symbols for the "do not enter" (shown in Figure 7) and biohazard concepts. Symbols such as these also must be learned to be understood. As a general principle, pictorials that directly represent the information, such as a the "wash hands" symbol showing two hands under a faucet, are recognized at a higher rate than pictorials representing abstract concepts.

What is an acceptable level of comprehension for pictorials? This question has been addressed in the ANSI (2006) Z535.3 standard, which suggests a goal of 85% comprehension by the target audience. There are two criteria that seem relevant here. The first is simply that pictorial symbols should be designed to accomplish the highest level of comprehension attainable. If 85% cannot be achieved, the symbol may still be useful if it is better than alternative designs. A second criterion is that the pictorial not be misinterpreted or communicate incorrect information. According to the ANSI (2006) Z535.3 standard, an acceptable symbol must have less than 5% critical confusions (opposite meaning or a meaning that would produce unsafe behavior). Research by Mayhorn and Goldsworthy (2007) illustrates an example of a misinterpretation of a pictorial that was part of a warning for the drug Accutane. 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 prohibition symbol. The intended meaning of the pictorial is that women should not take the drug if they are pregnant or plan to become pregnant. However, some women incorrectly interpreted the symbol 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 will eventually become habituated if repeatedly encountered. Sometimes the warning may become habituated with only partial knowledge. While there are no easy solutions to the habituation problem, one approach is to use attention-related features described in this chapter to slow the progress of habituation or to cause dishabituation compared to warnings without the features (Kim and Wogalter, 2009). However, there may be some utility in varying the warnings 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 likely habituated to them. Cigarette warnings in countries like Australia and Canada also have rotating warnings but also have large, highly explicit color pictured ones depicting severe consequences that are more likely to capture attention and reduce warning habituation relative to U.S. cigarette packages. Legislation regarding a U.S. Food and Drug Administration proposal is being considered to update cigarette package warnings to be similar in type to Australia's and Canada's.

Memory and Experience There are several ways to enhance safety knowledge. Employer training, mentioned earlier, is one method. Experience is another way that people acquire safety knowledge. "Learning the hard way" by having experienced an incident (or knowing someone who did) can certainly result in knowledge. Older adults commonly cite personal experience as a source of knowledge regarding hazards associated with household products such as cleaners and appliances (Mayhorn et al., 2004a). However, such experiences are not good experiences to have (!), and they do not necessarily produce accurate perceptions of risk. More on this topic will be given later in the section on beliefs and attitudes.

Warnings as Reminders Although individuals may have knowledge about 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-term and long-term memory distinction in cognitive psychology. Short-term, or working, memory is sometimes thought of as conscious awareness, which is known to have limitations. Long-term memory is the vast contents of 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 in their current awareness — or what they are thinking about. It is not enough to say that people know something. Rather, it is important that people be aware of 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. Warnings are insufficient solution in this case. A better solution was a procedural guard requiring the two hands to simultaneously activate separate controls for the press to punch. A similar example comes from hazards associated with farm equipment. Experienced farm workers are quite knowledgeable when asked about the dangers of power take-off (PTO) machinery on tractors, yet a large number of farmers interviewed in a recent study reported knowing someone that had gotten hurt or killed while using this device (McLaughlin and Mayhorn, 2011). Thus, the distinction between knowledge and awareness has implications for the role of warnings as reminders. Potentially warnings could serve to cue information in long-term memory to bring forth related and previously dormant knowledge into conscious awareness (Smith and Wogalter, 2010).

There are several circumstances in which warning reminders are useful and/or needed. Some of the more noteworthy are:

1. A hazardous situation or product (that is not open and obvious) is encountered infrequently where forgetting may be a factor.

2. Distractions occur during the performance of a task or the use of a product (e.g., environmental stimuli) that will compete for attention.
3. High task loads which exceed attentional capacity, limiting access to related knowledge (high mental workload and task involvement).

When warnings are intended to function only as reminders, it is not always necessary to provide the same information usually required as a full warning. With reminders, getting the person's attention is emphasized. The automobile driver who forgets to fasten the seat belt might be reminded by the buzzer and light warning. (Persons already habituated to cues may need the cues changed.) Another example is the personal digital assistant that can assist users in adhering to medication regimens by sounding an auditory signal when it is time to take a particular medication (Mayhorn et al., 2005). Technology provides the cues to prompt memory.

"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. That a knife can cut is apparent to all people except young children. The hazard and consequence of a fall from a height in a construction setting is considered open and obvious unless there are special circumstances. Many hazardous situations are not open and obvious. Some are associated with chemical hazards where labeling and warnings are necessary because the chemical itself might not make the hazard known. Another issue is an attentional one, in which one hazard attracts more attention than another. Hidden hazards have been documented in the agricultural context. Farmers working to repair tractors may actively work to avoid the dangers of moving parts but in doing that succumb to another hazard such as carbon monoxide in an enclosed space (McLaughlin and Mayhorn, 2011).

Technical Information Many warnings require an appreciation of technical information for full and complete understanding of the material. Examples include 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. While 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. Different components of the warning system can and often should be used to communicate to the different groups in the target audience.

Auditory Besides simple auditory alerts described earlier in the section on attention, auditory warnings may be used for the specific purpose of conveying particular meanings. These auditory warnings may be nonverbal (distinguishable sounds to cue different things) or verbal (voice).

Nonverbal Warnings Nonverbal auditory warnings can be further divided into simple and complex. Such simple warnings were mentioned in the context of the attention switch stage. Complex nonverbal signals are composed of sounds 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 signal means. Some form of education and training is necessary. Only a limited number of different nonverbal auditory signals should be used to avoid problems in discriminating and cuing their associated meaning (Banks and Boone, 1981; Cooper, 1977).

Voice Warnings Auditory warnings are also transmitted via voice (speech) as in a child being warned from afar by a caretaker. In recent years, voice chips and digitized sound processors have been developed, making voice warnings feasible for a wide range of applications. Under certain circumstances, voice warnings can be more effective in transmitting information than printed signs (Wogalter et al., 1993b; Wogalter and Young, 1991). Additionally voice modifications and manipulations can produce different levels of perceived urgency (Edworthy and Hellier, 2000; Hollander and Wogalter, 2000). Thus there is great promise for voice warnings as they will be increasingly incorporated into daily life. There are, however, some problems 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.

One example of previous research that has successfully demonstrated the utility of voice warnings is Conzola and Wogalter's (1999) "talking box" study. When participants opened the box, a miniaturized voice system delivered a sequence of precautionary steps to be performed before installing a computer disk drive in the box. With safety instructions that require numerous complex steps, working memory could be overloaded if the sequence is provided in one continuous presentation. A system that provides cognitive support by giving carefully timed or user-prompted instructions might be effective in reducing the likelihood of overloading the cognitive system.

4.4.3 Beliefs and Attitudes

If a warning successfully captures and maintains attention and is understood, it still might fail to elicit safety

behavior due to discrepant beliefs and attitudes held by the receiver. Beliefs refer to an individual'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 successfully processed at the beliefs-and-attitudes stage if the information concurs with the receiver's current beliefs and attitudes. The warning message is easily processed as this stage if it matches up (and concurrently reinforces) what the receiver already knows. In the process, it 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, the beliefs and attitudes must be altered by the warning for it to be effective. 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 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 drivers who believe their skills with driving will not suffer when they divide their attention by using cellular telephones (Strayer et al., 2003; Wogalter and Mayhorn, 2005b).

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, 1993a). Persons who do not perceive products as being hazardous are less likely to notice or read an associated warning (Wogalter et al., 1991; Wogalter et al., 1993a). 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 low if the consequence 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, 1993a). A person who is familiar with a piece of equipment might assume that a new, similar piece of equipment operates in the same way as their previous equipment. This may not actually be true, but due to their belief, the person does not read the product manual and as a result could be seriously injured. 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 of "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, with increased use of the product, people are exposed more frequently to the warnings, which can increase the opportunity to be influenced by them. Of course, warnings in tiny dense print may never be read even over many cycles of use. When there is a potential for the negative effects of familiarity to be a factor, stronger warnings may be needed or other efforts required. Clearly, hazardous products that are used repetitively pose special 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 lead to overestimation of the degree of danger. Similarly, the lack of such experiences may lead to underestimation of danger or not thinking about them at all (Wogalter et al., 1991, 1993a).

A related point concerns the problem of overestimating what people know. Experts in a domain may be so facile with that knowledge that they fail to realize that nonexperts do not have similar skills and knowledge. To the extent it is incorrectly assumed that people have information and knowledge, there may be a tendency to provide inadequate warnings. Fewer cues are necessary for experts to enlist large stores of knowledge relative to the general public. Thus, an important part of the job, environment, and product design is to take into account the target audience's understanding and knowledge of hazards and their consequences [see Laughery (1993) for a discussion of this topic].

4.4.4 Motivation

Even if people see, understand, and believe a warning, they may not comply with it. Motivation is very closely tied to behavior because it can serve to energize individuals to carry out activities that they might not otherwise do. Among the most influential factors for motivation with respect to warnings are 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 an increased likelihood that it will not be effective unless the consequences of noncompliance are perceived as 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. Cost of complying 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 warning analyses, when the instruction statement requires an inconvenient, difficult, or occasionally impossible behavior to carry out. "Always have two or more persons to lift [box or object]" cannot be done if no one else is around. "Wear rubber gloves when handling this product" is inconvenient to do if the user does not have easy access to appropriate gloves and a hardware store is not nearby.

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). A primary 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.

Also, the costs of noncompliance can affect compliance motivation and behavior. This effect is particularly true when the possible consequences of the hazards are severe. Injury 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 costs of compliance and noncompliance.

Severity of Consequences A related issue to costs of noncompliance is severity of consequences. Perceived severity of injury is intimately tied to risk perception, as discussed in the the section on beliefs and attitudes. Severity of injury is a major factor in people's reported willingness to comply with warnings. People's notions of hazardousness are almost entirely based on the seriousness of the potential outcome (Wogalter et al., 1991, 1993a). The likelihood of such events, however, is considered less readily in people's hazard-related judgments (Wogalter and Barlow, 1990; Young et al., 1990, 1992). These findings emphasize the importance of clear, explicit consequence 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 that others do 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. An example of a risky behavior that is strongly influenced by social interaction is the "sharing" of prescription medications by teenagers (Goldsworthy and Mayhorn, 2009; Goldsworthy et al., 2008b). Explicit warnings are needed to counteract misconceptions exacerbated by social factors.

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.

4.4.5 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 a warning will be effective in producing compliance or not. Silver and Braun (1999) and Kalsher and Williams (2006) have reviewed published research that has measured compliance with warnings under various conditions. Dingus and Wogalter (1999) showed 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). Due to the ethical concerns associated with exposing research participants to real hazards, many researchers have measured intentions to comply as a proxy for compliance behavior. Recently, Duarte et al. (2010) described the potential for virtual reality technology to enable the exploration of behavioral compliance without placing users at risk from physical harm, which is one of the main difficulties in doing research that measures actual behavioral compliance.

4.4.6 Demographic Factors

The above sections have provided a review of major concepts and findings organized on the basis of the C-HIP model. Newer versions of C-HIP (Wogalter, 2006a) give greater emphasis on demographics differences of receivers. 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 slightly greater 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, there are research results that show women are more likely to comply with warnings (Goldhaber and deTurck, 1988; Viscussi et al., 1986). However, many other studies either do not report or do not find a gender difference.

Regarding age, the results are mixed. There are results suggesting that people older than 40 are more likely to take precautions in response to warnings (Hancock et al., 2005; Mayhorn et al., 2004a; Mayhorn and Podany, 2006). However, some research (Wogalter and Vigilante, 2003; Wogalter et al., 1999d) has shown that

older adults have more difficulties reading small print on product labels than younger adults. Other research (Collins and Lerner, 1982; Easterby and Hakiel, 1981; Ringseis and Caird, 1995; Schroeder et al., 2001; Shorr et al., 2009) has shown that older subjects had lower levels of comprehension for safety-related symbols than younger adults. Results such as these suggest that older adults may be more influenced by warnings, but legibility and comprehension need to be considered in their design.

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.

4.4.7 Summary and Benefit of C-HIP

The above 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 a manufacturer finds that a critical warning on their product label is not working to prevent injury. The first reaction to solving the compliance problem might be to increase the size of the font so more people are likely to see it. But noticing the warning label (the attention switch stage) might not be the problem. Product testing might instead reveal that virtually 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) did not outweigh the small perceived risk about getting injured. The point here is that one could use the model to pinpoint the causes of the warning not working and try to remedy it by targeted means. 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 a wrong aspect of the warning's 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. The failure to give a persuasive statements and a conspicuous presentation could result in low effectiveness. The failure to provide explicit consequences information when the outcome of noncompliance is catastrophic is inconsistent with warning adequacy criteria regarding motivation. Considerations such as these can be useful in formulating opinions and addressing issues on why a warning was not successful.

5 DESIGNING FOR APPLICATION

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

5.1 Standards

A starting point in designing warnings is to consider existing guidelines such as the ANSI (2006) Z535, FMC Corporation (1985), or Westinghouse Electric Corporation (1981). ANSI Z535 is currently a six-part standard which includes descriptions of safety colors, signs, symbols, labels, tags, and ancillary materials. ANSI standards are voluntary standards; that is, they are only recommendations and are generally considered "minimums." We believe that blindly following the ANSI standard will not lead to great warnings. There is a need for some human factors judgment and testing to fine tune the warning for the particular product or situation. In the ANSI Z535 standard, there is an emphasis on a standardized way to format signs (Z535.2) and product labels (Z535.4). According to these standards, warning signs and labels should possess the following 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 briefly describes the nature of the hazard, (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 can provide benefit to warning efficacy. There may be exceptions when one (or more) of the message components are 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, assuming understandable symbols are used. Safety symbols should meet certain comprehension criteria to be acceptable for use by itself (without words). Both

the ANSI (2006) Z535.3 and the International Organization for Standardization (ISO, 2001) 9186 symbol standards provide guidelines and methods to assess symbol comprehension.

5.2 Checklist of Potential Warning Components

Use of only standards and guidelines may not always produce an effective warning. Table 2 presents 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. Examples of measurement methods are also provided in the table. While not an exhaustive list, the table contains a set of factors that the warning literature indicates should be considered in warning design. Thus, one method of assessing warning quality is simply to determine the extent to which the design meets appropriate criteria such as those given in Table 2. With respect to attention, the effectiveness of the warning might be questioned if

Table 2 Warning Design Guidelines

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

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. With respect to comprehension, if the reading level is high, technical language is used, or the statements are vague and not explicit, then the warning may not be interpreted as intended. Similar considerations can be applied with respect to the criteria for the other stages.

Implementation of specific factors may also depend on situational-specific considerations such as target audience knowledge and/or characteristics of the product. For example, some warning components may not be necessary if the target audience consists of trained experts or if the information is apparent from other aspects of the situation.

5.3 Principles

In addition to the factors specified in Table 2, there are several other important principles or general guidelines that should be considered when designing warning systems. These principles are described in the following sections.

5.3.1 Principle 1: 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. Thus, the brevity criterion conflicts to some extent with the explicitness criterion. Being explicit about every hazard could result in very long warnings. Obviously, the brevity criterion should not be interpreted as a license to omit important information. A "happy medium" between brevity and completeness is discussed in the next section on prioritization.

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 cited from overwarning is that people may not attend to them or may become highly selective, attending only to some warnings. The notion is that if warnings were to be placed on everything, people would simply ignore them. While this notion has face validity, there has been little empirical data assessing the limits implied. Nevertheless, overwarning may be a valid concern, and unnecessary warnings should be avoided.

An important issue related to overwarning that frequently arises in litigation is the absence of certain information. An argument that is sometimes made is that information being left off was somehow a benefit to consumers because its inclusion would hurt the likelihood of other important information being read. However, this is often just a post hoc defense and it does not comport with "right to know." The notion of informed consent says that warnings should provide to people the opportunity to know about hazards. Indeed, research indicates that people want to know about hazards even if is difficult to give definitive risk information (Freeman and Wogalter, 2002; Cheatham and Wogalter, 2003). Prioritization, discussed in the next section, is a useful approach in dealing with warnings for products and equipment that have multiple hazards.

5.3.2 Principle 2: Prioritization

Prioritization concerns what hazards to warn about and to emphasize when multiple hazards exist. How are priorities defined in deciding what to include/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, 1997b), considerations include:

1. *Likelihood*. The more frequently an undesirable event occurs, the greater the priority it should be given as a warning.
2. *Severity*. The more severe the potential consequences of a hazard, the greater priority 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 individuals 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.

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 on the product label. If not practical to place them all on the label, those with lower priority might go on other warning system components such as package inserts, manuals, websites, or other media.

5.3.3 Principle 3: Know the Receiver

Gather information and data about relevant receiver characteristics. To illustrate such an effort, Goldsworthy et al. (2010) describe an analytic technique known as latent class analysis (LCA) to facilitate the tailoring of warning content designed to prevent the sharing and exchanging of prescription medications. Receiver-centered testing of the target audience was particularly important because of the complex risk-related scenarios involved.

A related way to meet the needs of receivers is to purposely tailor for the warning as appropriate to the person, product, and/or situation. One approach to tailoring warnings can be accomplished through the use of technology, such as using sensors, computers, software, and displays (Wogalter and Mayhorn, 2005a). To

provide such customization, data must be collected and quickly processed to anticipate and present the needed warning information at the appropriate time. Users could carry relevant data with him or her. Currently, there are "smart" credit cards that contain user information and wireless electronic tags that can transmit information within a short proximity (e.g., ExxonMobil's Smart Pass, which identifies credit customers by passing an electronic key near the face of the gas pump). Advanced warning systems would be able to supply information tailored to meet people's particular needs.

5.3.4 Principle 4: Design for Low-End Receiver

When there is variability in the target population, which is almost always the case with 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. Likewise, formatting and presentation should take into consideration those who are older, perceptually disabled, and otherwise unable to access the warning information. An added benefit of designing warning systems for the low-end user is the realization that these solutions typically result in more user-friendly products and environments that benefit all consumers regardless of ability and demographic differences (Vanderheiden, 1997).

5.3.5 Principle 5: 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 for the different subgroups. Do not assume that everything will be accomplished with a single warning or warning method.

5.3.6 Principle 6: Durability

Warnings should be designed to last as long as needed. There are circumstances where durability is typically not a problem. A product purchased off the shelf of a drug store that will be completely and immediately consumed is an example. On the other hand, products with a long lifespan, such as cars and lawn mowers, may present a challenge (Glasscock and Dorris, 2006). Similarly, in situations where warnings are exposed to weather such as on construction sites or extensive handling such as on some containers, durability problems can influence comprehension (Shorr et al., 2009). Some products have manuals that list warning labels with part numbers, presumably to enable ordering label replacements when needed. Undoubtedly replacement labels are not frequently ordered, a factor that suggests the original labels should be as durable as possible so as to last to the high-end range of the expected life of the product.

Related to durability is ancillary material that accompanies the product when originally purchased as new. Warnings may be printed on a an outer container box or packaging and on an insert or in an owner's manual. These ancillary materials may not be available at later uses of the product. The box or packaging may be discarded (Cheatham and Wogalter, 2003) or the owner's manual may be discarded or misplaced (Wogalter et al., 1998b) or never transferred to subsequent owners or users of a product (Mehlenbacher et al., 2002). This is why consideration of what warnings to place directly on a product (or on a container) is critical because they may be the only ones available to users at later points in time.

5.3.7 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 while also considering practicality and feasibility.

To assess attention, a warning could be placed on a product and have people 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 and quickly and at low cost. Well-established methodologies involving memory tests, open-ended response tests, interviews, and so on, are applicable. While the qualitative data that result from open-ended and interview methodologies can be problematic, 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 to be applicable to them (beliefs and attitudes). Negative results on these dimensions would indicate the warning lacks sufficient persuasiveness. Motivation can be assessed by obtaining measures of compliance intentions. While such intention measures will generally reflect higher levels than 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 likely be more effective.

While behavioral compliance studies are generally difficult to execute, in situations where negative consequences of an ineffective warning are high, the effort may be warranted. As mentioned earlier, a possible alternative is to utilize virtual reality methodology to avoid such ethical issues (Duarte et al., 2010). If such technology is not available, behavioral intentions can be measured as a proxy for behavioral data. Poor warnings tend to result from no testing whatsoever.

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, guarding against contamination by expected outcomes, and determining the best coding rubric to assess qualitative comprehension data from open-ended assessments 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), Kalsher and Williams (2006), Mayhorn and Goldsworthy (2009), Wogalter and Dingus (1999), Young and Lovvoll (1999), and Wogalter et al. (1999a).

6 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 research, guidelines, and criteria for designing warnings.

Approaches to dealing with environmental or product hazards are generally prioritized such that the first one 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 be properly 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 kinds 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, the C-HIP model was described. It involves 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. Its potential use as an investigative tool was also discussed.

Determining whether or not a warning will influence behavior is often a difficult assignment. In addition to 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, while 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 that shows people do not comply with a warning may not tell us if it failed because it was not noticed, because it was not understood, 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 improved warning designs.

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 provides useful input toward the goal of providing effective warnings.

REFERENCES

American National Standards Institute (ANSI) (2006), *Accredited Standards Committee on Safety Signs and Colors. Z535.1-6*, National Electrical Manufacturers Association, Arlington, VA.

Banks, W. W., and Boone, M. P. (1981), *Nuclear Control Room Enunciators: Problems and Recommendations*, NUREG/CR-2147, National Technical Information Service, Springfield, VA.

Barlow, T., and Wogalter, M. S. (1991), "Increasing the Surface Area on Small Product Containers to Facilitate Communication of Label Information and Warnings," in *Proceedings of Interface 91*, Human Factors Society, Santa Monica. CA, pp. 88–93.

Barlow, T., and Wogalter, M. S. (1993), "Alcoholic Beverage Warnings in Magazine and Television Advertisements," *Journal of Consumer Research*, Vol. 20, pp. 147–155.

Barzegar, R. S., and Wogalter, M. S. (1998), "Intended Carefulness for Voiced Warning Signal Words," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 42, pp. 1068–1072.

Boersema, T., and Zwaga, H. J. G. (1989), "Selecting Comprehensible Warning Symbols for Swimming Pool Slides," *Proceedings of the Human Factors Society*, Vol. 33, pp. 994–998.

Bzostek, J. A., and Wogalter, M. S. (1999), "Measuring Visual Search Time for a Product Warning Label as a Function of Icon, Color, Column, and Vertical Placement," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 43, pp. 888–892.

Casey, S. (1998), *Set Phasers* On *Stun: And Other True Tales* Of *Design, Technology,* And *Human Error*, 2nd ed., Aegean Publishing, Santa Barbara, CA.

Chapanis, A. (1994), "Hazards Associated with Three Signal Words and Four Colours on Warning Signs," *Ergonomics*, Vol. 37, pp. 265–275.

Cheatham, D. B., and Wogalter, M. S. (2003), "Comprehension of Over-the-Counter Drug Label Warnings Regarding Consumption of Acetaminophen and Alcohol,"

Proceedings of the Human Factors and Ergonomics Society, Vol. 47, pp. 1540–1544.

Collins, B. L. (1983), "Evaluation of Mine-Safety Symbols," *Proceedings of the Human Factors Society*, Vol. 27, pp. 947–949.

Collins, B. L., and Lerner, N. D. (1982), "Assessment of Fire-Safety Symbols," *Human Factors*, Vol. 24, pp. 75–84.

Conzola, V. C., and Wogalter, M. S. (1999), "Using Voice and Print Directives and Warnings to Supplement Product Manual Instructions," *International Journal of Industrial Ergonomics*, Vol. 23, pp. 549–556.

Cooper, G. E. (1977), *A Survey of the Status and Philosophies Relating to Cockpit Warning Systems*, NASA-CR-152071, NASA Ames Research Center, Moffett Field, CA.

Cox, E. P. III, Wogalter, M. S., Stokes, S. L., and Murff, E. J. T. (1997), "Do Product Warnings Increase Safe Behavior?: A Meta-Analysis," *Journal of Public Policy and Marketing*, Vol. 16, pp. 195–204.

Desaulniers, D. R. (1987), "Layout, Organization, and the Effectiveness of Consumer Product Warnings," *Proceedings of the Human Factors Society*, Vol. 31, pp. 56–60.

DeJoy, D. M. (1999), "Beliefs and Attitudes," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 183–219.

Dewar, R., (1999), "Design and Evaluation of Graphic Symbols," in *Visual Information for Everyday Use: Design and Research Perspectives*, H. J. G. Zwaga, T. Boersema, and H. C. M. Hoonhout, Eds., Taylor and Francis, London, pp. 285–303.

Dingus, T. A., Hathaway, J. A., and Hunn, B. P. (1991), "A Most Critical Warning Variable: Two Demonstrations of the Powerful Effects of Cost on Warning Compliance," *Proceedings of the Human Factors Society*, Vol. 35, pp. 1034–1038.

Donner, K. A. (1991), "Prediction of Safety Behaviors from Locus of Control Statements," in *Interface '91', Proceedings of the 7th Symposium on Human Factors and Industrial Design in Consumer Products*, Human Factors Society, Santa Monica, CA, pp. 94–98.

Duarte, M. E. C., Rebelo, F., and Wogalter, M. S. (2010), "The Potential of Virtual Reality (VR) for Evaluating Warning Compliance," *Human Factors and Ergonomics in Manufacturing and Service Industries*, Vol. 20 pp. 526–537.

Duffy, T. M. (1985), "Readability Formulas: What's The Use?," in *Designing Usable Texts*, T.M. Duffy and R. Waller, Eds., Academic Press, Orlando, FL.

Easterby, R. S., and Hakiel, S. R. (1981), "The Comprehension of Pictorially Presented Messages," *Applied Ergonomics*, Vol. 12, pp. 143–152.

Edworthy, J., and Hellier, E. J. (2000), "Auditory Warnings in Noisy Environments," *Noise and Health*, Vol. 6, pp. 27–39.

Edworthy, J. Loxley, S., and Dennis, I. (1991), "Improving Auditory Warning Design: Relationship between Warning Sound Parameters and Perceived Urgency," *Human Factors*, Vol. 33, pp. 205–231

FMC Corporation (1985), *Product Safety Sign and Label System*, FMC Corporation, Santa Clara, CA.

Frantz, J. P., and Rhoades, T. P. (1993), "A Task Analytic Approach to the Temporal Placement of Product Warnings," *Human Factors*, Vol. 35, pp. 719–730.

Frantz, J. P., Rhoades, T. P., and Lehto, M. R. (1999), "Practical Considerations Regarding the Design and Evaluation of Product Warnings," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 291–311.

Freeman, K., and Wogalter, M. S. (2002), "On Informing Women of Child Bearing Age about Seat Belt Risk during Pregnancy," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 46, pp. 943–946.

Glasscock, N. F. and Dorris, N. T. (2006), "Warning Degradation and Durability," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 499–511.

Godfrey, S. S., and Laughery, K. R. (1984), "The Biasing Effect of Familiarity on Consumer's Awareness of Hazard," *Proceedings of the Human Factors Society*, Vol. 28, pp. 483–486.

Godfrey, S. S., Allender, L., Laughery, K. R., and Smith, V. L. (1983), "Warning Messages: Will the Consumer Bother To Look?" *Proceedings of the Human Factors* Society, Vol. 27, pp. 950–954.

Goldhaber, G. M., and deTurck, M. A. (1988), "Effects of Consumer's Familiarity with a Product on Attention and Compliance with Warnings," *Journal of Products Liability*, Vol. 11, pp. 29–37.

Goldsworthy, R. C. and Mayhorn, C. B. (2009), "Prescription Medication Sharing among Adolescents: Prevalence, Risks, and Outcomes," *Journal of Adolescent Health*, Vol. 45, No. 6, pp. 634–637.

Goldsworthy, R. C., and Mayhorn, C. B. (2010), "Direct to Consumer (DTC) Prescription Drug Advertising: Exploring Self Reports of Media Exposure and Associated Behaviors," in *Proceedings of the Third Applied Human Factors and Ergonomics International Conference*, Miami, FL.

Goldsworthy, R. C., Schwartz, N., and Mayhorn, C. B. (2008a), "Interpretation of Pharmaceutical Warnings among Adolescents," *Journal of Adolescent Health*, Vol. 42, No. 6, pp. 617–625.

Goldsworthy, R. C., Schwartz, N., and Mayhorn, C. B. (2008b), "Beyond Abuse and Exposure: Framing the Impact of Prescription Medication Sharing," *American Journal of Public Health*, Vol. 98, No. 6, pp. 1115–1121.

Goldsworthy, R. C., Mayhorn, C. B., and Meade, A. W. (2010), "Warnings in Manufacturing: Improving Hazard Mitigation Messaging through Audience Analysis," *Human Factors and Ergonomics in Manufacturing and Service Industries*, Vol. 20, No. 6, pp. 484–499.

Hancock, H. E., Fisk, A. D., and Rogers, W. A. (2005), "Comprehending Product Warning Information: Age-Related Effects and the Roles of Memory, Inferencing, and Knowledge," *Human Factors*, Vol. 47, No. 2, pp. 219–234.

Hartley, J. (1994), *Designing Instructional Text*, 3rd ed., Kogan Page, London/ Nichols, East Brunswick, NJ.

Hellier, E., Edworthy, J., Weedon, B, Walters, K, and Adams, A. (2002), "The Perceived Urgency of Speech Warnings: Semantics versus Acoustics," *Human Factors*, Vol. 44, pp. 1–17.

Hollander, T. D., and Wogalter, M. S. (2000), "Connoted Hazard of Voice Warning Signal Words: An Examination of Auditory Components," *Proceedings of the International Ergonomics Association and the Human Factors and Ergonomics Society Congress*, Vol. 44, No. 3, pp. 702–705.

International Organization for Standardization (ISO) (2001), *Graphical Symbols–Test Methods For Judged Comprehensibility And For Comprehension*, ISO 9186, ISO, Geneva.

Jaynes, L. S., and Boles, D. B. (1990), "The Effects of Symbols on Warning Compliance," *Proceedings of the Human Factors* Society, Vo. 34, pp. 984–987.

Kalsher, M. J., and Williams, K. J. (2006), "Behavioral Compliance: Theory, Methodology, and Results," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, Chapter 23, pp. 313–331.

Kalsher, M. J., Wogalter, M. S., and Racicot, B. M. (1996), "Pharmaceutical Container Labels and Warnings: Preference and Perceived Readability of Alternative Designs and Pictorials," *International Journal of Industrial Ergonomics*, Vol. 18, pp. 83–90.

Kim, S., Mayhorn, C. B., and Wogalter, M. S. (2010), "Use of Information Sources Referenced in and Attitudes about Televised DTC Prescription Drug Advertisements," in *Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 1880–1884..

LaRue, C., and Cohen, H. (1987), "Factors Influencing Consumer's Perceptions of Warning: An Examination of the Differences between Male and Female Consumers," *Proceedings of the Human Factors Society*, Vol. 31, pp. 610–614.

Lasswell, H. D. (1948), "The Structure and Function of Communication in Society," in *The Communication of Ideas*, L. Bryson, Ed., Wiley, New York.

Laughery, K. R. (1993), "Everybody Knows: Or Do They?" *Ergonomics in Design*, July, pp. 8–13.

Laughery, K .R., and Brelsford, J. W. (1991), "Receiver Characteristics in Safety Communications," *Proceedings of the Human Factors Society*, Vol. 35, pp. 1068–1072.

Laughery, K. R., and Paige-Smith, D. (2006), "Explicit Information in Warnings," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, Chapter 31, pp. 419–428.

Laughery, K. R., and Wogalter, M. S. (2011), "The Hazard-Control Hierarchy and Its Utility in Safety Decisions about Consumer Products," in *Handbook of Human Factors and Ergonomics in Consumer Product Design: Uses and Applications*, Vol. 2, W. Karwowski, M. Soares, and N. Stanton (Eds), CRC Press, Boca Raton, FL, pp. 33–40.

Laughery, K. R., Vaubel, K. P., Young, S. L., Brelsford, J. W., and Rowe, A. L. (1993a), "Explicitness of Consequence Information In Warning," *Safety Science*, Vol. 16, pp. 597–613.

Laughery, K. R., Young, S. L., Vaubel, K .P., and Brelsford, J. W. (1993b), "The Noticeability of Warnings on Alcoholic Beverage Containers," *Journal of Public Policy and Marketing*, Vol. 12, pp. 38–56.

Laughery, K. R., Wogalter, M. S., and Young, S. L., Eds. (1994), *Human Factors Perspectives on Warnings: Selections from Human Factors and Ergonomics Society Annual Meetings 1980–1993*, Human Factors and Ergonomics Society, Santa Monica, CA.

Laux, L., and Brelsford, J. W. (1989) "Locus of Control, Risk Perception, and Precautionary Behavior," *Proceedings of Interface 89—Sixth Symposium on Human Factors and Industrial Design in Consumer Products*, Human Factors Society, Santa Monica, CA, pp. 121–124.

Laux, L. F., Mayer, D. L., and Thompson, N. B. (1989), "Usefulness of Symbols and Pictorials to Communicate Hazard Information," in *Proceedings of the Interface 89—Sixth Symposium on Human Factors and Industrial Design in Consumer Products*, Human Factors Society, Santa Monica, CA, pp. 79–93.

Lehto, M. R., and Miller, J. M. (1986), *Warnings*, Vol. 1, *Fundamentals, Design and Evaluation Methodologies*, Fuller Technical Publications, Ann Arbor, MI.

Lehto, M. R., and Papastavrou, J. D. (1993), "Models of the Warning Process: Important Implications towards Effectiveness," *Safety Science*, Vol. 16, pp. 569–595.

Lehto, M. R., and Salvendy, G. (1995), "Warnings: A Supplement not a Substitute for Other Approaches to Safety," *Ergonomics*, Vol. 38, pp. 2155–2163.

Lerner, N. D., and Collins, B. L. (1980), "The Assessment of Safety Symbol Understandability by Different Testing Methods," PB81-185647, National Bureau of Standards, Washington, DC.

Lim, R. W., and Wogalter, M. S. (2003), "Beliefs about Bilingual Labels on Consumer Products," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 47, pp. 839–843.

Lust, J. A., Celuch, K. G., and Showers, L. S. (1993), "A Note on Issues Concerning the Measurement of Self-Efficacy," *Journal of Applied Social Psychology*, Vol. 23, pp. 1426–1434.

Madden, M. S. (1999), "The Law Related to Warnings," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 315–329.

Mayhorn, C. B., and Goldsworthy, R. C. (2007), "Refining Teratogen Warning Symbols for Diverse Populations," *Birth Defects Research Part A: Clinical and Molecular Teratology*, Vol. 79, No. 6, pp. 494–506.

Mayhorn, C. B., and Goldsworthy, R. C. (2009). "'New And Improved': The Role Text Augmentation and the Application of Responses Interpretation Standards (Coding Schemes) in a Final Iteration of Birth Defects Warnings Development," *Birth Defects Research Part A: Clinical and Molecular Teratology*, Vol. 85, No. 10, pp. 864–871.

Mayhorn, C. B., and Podany, K. I. (2006), "Older Adults and Warnings," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 355–361.

Mayhorn, C. B., Nichols, T. A., Rogers, W. A., and Fisk, A. D. (2004a), "Hazards in the Home: Using Older Adults' Perceptions to Inform Warning Design," *Journal of Injury Control and Safety Promotion*, Vol. 11, No. 4, pp. 211–218.

Mayhorn, C. B., Wogalter, M. S., and Bell, J. L. (2004b), "Are We Ready? Misunderstanding Homeland Security Safety Symbols," *Ergonomics in Design*, Vol. 12, No. 4, pp. 6–14.

Mayhorn, C. B., Wogalter, M. S., and Shaver, E. F. (2004c), "What Does Code Red Mean?" *Ergonomics in Design*, Vol. 2, No. 4, p. 12.

Mayhorn, C. B., Lanzolla, V. R., Wogalter, M. S., and Watson, A. M. (2005), "Personal Digital Assistants (PDAs) as Medication Reminding Tools: Exploring Age Differences in Usability," *Gerontechnology*, Vol. 4, No. 3, pp. 128–140.

Mayhorn, C. B., Wogalter, M. S., and Mendat, C. C. (2006), "The Matching Game: Educating Children about Household Hazards and Warning Symbols," in *Proceedings of the 16th World Congress of the International Ergonomics Association*, Maastricht, The Netherlands.

McLaughlin, A. C., and Mayhorn, C. B. (2011), "Avoiding Harm on the Farm: The Need for Human Factors in Understanding Safety in a Global Agricultural Context", *Gerontechnology*, Vol. 10, No. 1, pp. 26–37.

Mehlenbacher, B., Wogalter, M. S., and Laughery, K. R. (2002), "On the Reading of Product Owner's Manuals: Perceptions and Product Complexity," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 46, pp. 730–734.

Otsubo, S. M. (1988), "A Behavioral Study of Warning Labels for Consumer Products: Perceived Danger and Use of Pictographs," *Proceedings of the Human Factors Society*, Vol. 32, pp. 536–540.

Penney, C. G. (1989), "Modality Effects and the Structure of Short-Term Verbal Memory," *Memory and Cognition*, Vol. 17, pp. 398–422.

Rhoades, T. P., Frantz, J. P., and Hopp, K. M. (1991), "Product Information: Is It Transferred to the Second Owner of a Product?" in *Proceedings of Interface '91'*, Human Factors Society, Santa Monica, CA, pp. 100–104.

Ringseis, E. L., and Caird, J. K. (1995), "The Comprehensibility and Legibility of Twenty Pharmaceutical Warning Pictograms," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 39, pp. pp. 974–978.

Rogers, W. A., Lamson, N., and Rouseau, G.K. (2000), "Warning Research: An Integrative Perspective," *Human Factors*, Vol. 42, pp. 102–139.

Sanders, M. S., and McCormick, E. J. (1993), *Human Factors in Engineering and Design*, 7th ed., McGraw-Hill, New York.

Schroeder, D. G., Hancock, H. E., Rogers, W. A., and Fisk, A. D. (2001), "Phrase Generation and Symbol Comprehension for 40 Safety Symbols," in *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 1470–1480.

Shannon, C. E., and Weaver, W. (1949), *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, IL.

Shorr, D. J., Ezer, N., Fisk, A. D., and Rogers, W.A. (2009), "Comprehension of Warning Symbols by Younger and Older Adults: Effects of Visual Degradation," in *Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 1598–1602.

Silver, N. C., and Braun, C. C. (1999), "Behavior," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 245–262.

Smith, J. J.., and Wogalter, M. S. (2010), "Behavioral Compliance to In-Manual and On-Product Warnings," in *Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 1846–1850.

Smith-Jackson, T. (2006a), "Culture and Warnings," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 363–372.

Smith-Jackson, T. L. (2006b), "Receiver Characteristics," in *Handbook of Warnings*. M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 335–344.

Smith-Jackson, T. L., and Wogalter, M. S. (2000), "Applying Cultural Ergonomics/Human Factors to Safety Information Research," *Proceedings of the International Ergonomics Association and the Human Factors and Ergonomics Society Congress*, Vol. 44, No. 6, pp. 150–153.

Smith-Jackson, T. L., and Wogalter, M. S. (2007), "Application of Mental Models Approach to MSDS Design," *Theoretical Issues in Ergonomics Science*, Vol. 8, pp. 303–319.

Sorkin, R. D. (1987), "Design of Auditory and Tactile Displays," in *Handbook of Human Factors*, G. Salvendy, Ed., Wiley, New York.

Strayer, D. L., Drews, F. A., and Johnston, W. A. (2003), "Cell Phone-Induced Failures of Visual Attention during Simulated Driving," *Journal of Experimental Psychology: Applied*, Vol. 9, No. 1, pp. 23–32.

Tam, T. W., and Greenfield, T. K. (2010), "Do Alcohol Warnings Influence Men's and Women's Attempts to Deter Others from Driving While Intoxicated?" *Human Factors and Ergonomics in Manufacturing Service Industries*, Vol. 29, No. 6, pp. 538–546.

Vanderheiden, G. C. (1997), "Designing for People with Functional Limitations Resulting from Disability, Aging, or Circumstance," in *Handbook of Human Factors and Ergonomics*, 2nd ed., G. Salvendy, Ed., Wiley, New York, pp. 2010–2052.

Vigilante Jr., W. J., and Wogalter, M. S. (1997a), "On the Prioritization of Safety Warnings in Product Manuals," *International Journal of Industrial Ergonomics*, Vol. 20, pp. 277–285.

Vigilante, Jr., W. J.., and Wogalter, M. S. (1997b), "The Preferred Order of Over-the-Counter (OTC) Pharmaceutical Label Components," *Drug Information Journal*, Vol. 31, pp. 973–988.

Vigilante, Jr., W. J., Mayhorn, C. B., and Wogalter, M. S. (2007), "Direct-to-Consumer (DTC) Drug Advertising on Television and Online Purchases of Medications," in *Proceedings of the Human Factors and Ergonomics Society 51st Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 1272–1276.

Viscussi, W. K., Magat, W. A., and Huber, J. (1986), "Informational Regulation of Consumer Health Risks: An Empirical Evaluation of Hazard Warnings," *Rand Journal of Economics*, Vol. 17, pp. 351–365.

Vredenburgh, A. G., and Helmick-Rich, J. (2006), "Extrinsic Nonwarning Factors," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 373–382.

Weedon, B., Hellier, E. Edworthy, J., and Walters, K. (2000), "Perceived Urgency in Speech Warnings," *Proceedings of the International Ergonomics Association and the Human Factors and Ergonomics Society Congress*, Vol. 44, No. 3, pp. 690–693

Westinghouse Electric Corporation (1981), *Product Safety Label Handbook*, Westinghouse Printing Division, Trafford, PA.

Williamson, R. B. (2006), "Fire Warnings," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, pp. 701–710.

Wogalter, M. S. (1999), "Factors Influencing the Effectiveness of Warnings," in *Visual Information for Everyday Use: Design and Research Perspectives*, H. J. G. Zwaga, T. Boersema, and H. C. M. Hoonhout, Eds., Taylor and Francis, London, pp. 93–110.

Wogalter, M. S. (2006a), "Communication-Human Information Processing (C-HIP) Model," in *Handbook of Warnings*, M. S. Wogalter, Ed., Lawrence Erlbaum Associates, Mahwah, NJ, Chapter 5, pp. 51–61.

Wogalter, M. S., Ed. (2006b), *Handbook of Warnings*, Lawrence Erlbaum Associates, Mahwah, NJ (CRC Press, Boca Raton, FL).

Wogalter, M.S., and Barlow, T. (1990), "Injury Likelihood and Severity in Warnings," *Proceedings of the Human Factors Society*, Vol. 34, pp. 580–583.

Wogalter, M. S., and Brelsford, J. W. (1994), "Incidental Exposure to Rotating Warnings on Alcoholic Beverage Labels," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 38, pp. 374–378.

Wogalter, M. S., and Dingus, T. A. (1999), "Methodological Techniques for Evaluating Behavioral Intentions and Compliance," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 53–82.

Wogalter, M. S., and Feng, E. (2010), "Indirect Warnings/Instructions Produce Behavioral Compliance," *Human Factors and Ergonomics in Manufacturing and Service Industries*, Vol. 20, pp. 500–510.

Wogalter, M. S., and Laughery, K. R. (1996), "WARNING: Sign and Label Effectiveness," *Current Directions in Psychology*, Vol. 5, pp. 33–37.

Wogalter, M. S., and Laughery, K. R. (2005), "Effectiveness of Consumer Product Warnings: Design and Forensic Considerations," in *Handbook of Human Factors in Litigation*, I. Noy and W. Karwowski, Eds., Taylor and Francis, London.

Wogalter, M. S., and Leonard, S. D. (1999), "Attention Capture and Maintenance," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 123–148.

Wogalter, M. S., and Mayhorn, C. B. (2005a), "Perceptions of Driver Distraction Due to Cellular Phones by Cellular Phone Owners and Non-Owners," *Human Factors*, Vol. 47, No. 2, pp. 455–467.

Wogalter, M. S., and Mayhorn, C. B. (2005b), "Providing Cognitive Support with Technology-Based Warning Systems," *Ergonomics*, Vol. 48, No. 5, pp. 522–533.

Wogalter, M. S., and Mayhorn, C. B. (2008), "Trusting the Internet: Cues Affecting Perceived Credibility," *International Journal of Technology and Human Interaction*, Vol. 4, No. 1, pp. 76–94.

Wogalter, M. S., and Post, M. P. (1989), "Printed Computer Instructions: The Effects of Screen Pictographs and Text Format on Task Performance," in *Proceedings of Interface 89*, Human Factors Society, Santa Monica, CA pp. 133–138.

Wogalter, M. S., and Silver, N. C. (1995), "Warning Signal Words: Connoted Strength and Understandability by Children, Elders, and Non-Native English Speakers," *Ergonomics*, Vol. 38, pp. 2188–2206.

Wogalter, M .S., and Usher, M. (1999), "Effects of Concurrent Cognitive Task Loading on Warning Compliance Behavior," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 43, pp. 106–110.

Wogalter, M. S., and Vigilante, W. J. Jr. (2003), "Effects of Label Format on Knowledge Acquisition and Perceived Readability by Younger and Older Adults," *Ergonomics*, pp. 327–344.

Wogalter, M. S., and Young, S. L. (1991), "Behavioural Compliance to Voice and Print Warnings," *Ergonomics*, Vol. 34, pp. 79–89.

Wogalter, M. S., and Young, S. L. (1994), "Enhancing Warning Compliance through Alternative Product Label Designs," *Applied Ergonomics*, Vol. 25, pp. 53–57.

Wogalter, M. S., Godfrey, S. S., Fontenelle, G. A., Desaulniers, D. R., Rothstein, P. R., and Laughery, K. R. (1987), "Effectiveness of Warnings," *Human Factors*, Vol. 29, pp. 599–612.

Wogalter, M. S., Allison, S. T., and McKenna, N. (1989), "Effects of Cost and Social Influence on Warning Compliance," *Human Factors*, Vol. 31, pp. 133–140.

Wogalter, M. S., Brelsford, J. W., Desaulniers, D. R., and Laughery, K. R. (1991), "Consumer Product Warnings: The Role of Hazard Perception," *Journal of Safety Research*, Vol. 22, pp. 71–82.

Wogalter, M. S., Brems, D. J., and Martin, E. G. (1993a), "Risk Perception of Common Consumer Products: Judgments of Accident Frequency and Precautionary Intent," *Journal of Safety Research*, Vol. 24, pp. 97–106.

Wogalter, M. S., Kalsher, J. J., and Racicot, B. (1993b), "Behavioral Compliance with Warnings: Effects of Voice, Context and Location," *Safety Science*, Vol. 16, pp. 637–654.

Wogalter, M. S., Barlow, T., and Murphy, S. (1995), "Compliance to Owner's Manual Warnings: Influence of Familiarity and the Task-Relevant Placement of a Supplemental Directive," *Ergonomics*, Vol. 38, pp. 1081–1091.

Wogalter, M. S., Laughery, K. R., and Barfield, D. A. (1997), "Effect of Container Shape on Hazard Perceptions," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 41, pp. 390–394.

Wogalter, M. S., Magurno, A. B., Rashid, R., and Klein, K. W. (1998a), "The Influence of Time Stress and Location on Behavioral Compliance," *Safety Science*, Vol. 29, pp. 143–158.

Wogalter, M. S., Vigilante, W. J., and Baneth, R. C. (1998b), "Availability of Operator Manuals for Used Consumer Products," *Applied Ergonomics*, Vol. 29, pp. 193–200.

Wogalter, M. S., Conzola, V. C., and Vigilante, W. J. (1999a), "Applying Usability Engineering Principles to the Design and Testing of Warning Messages," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 43, pp. 921–925.

Wogalter, M. S., DeJoy, D. M., and Laughery, K. R. (1999b), "Organizing Framework: A Consolidated Communication-Human Information Processing (C-HIP) Model," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 15–24.

Wogalter, M. S., Kalsher, M. J., and Rashid. R. (1999c), "Effect of Signal Word and Source Attribution on Judgments of Warning Credibility and Compliance Likelihood," *International Journal of Industrial Ergonomics*, Vol. 24, pp. 185–192.

Wogalter, M. S., Magurno, A. B., Dietrich, D., and Scott, K. (1999d), "Enhancing Information Acquisition for Over-the-Counter Medications by Making Better Use of Container Surface Space," *Experimental Aging Research*, Vol. 25, pp. 27–48.

Wogalter, M. S., Young, S. L., and Laughery, K. R., Eds. (2001), *Human Factors Perspectives on Warnings*, Vol. 2, *Selections from Human Factors and Ergonomics*

Society Annual Meetings 1993–2000, Human Factors and Ergonomics Society, Santa Monica, CA.

Wolff, J. S., and Wogalter, M. S., (1993), "Test and Development of Pharmaceutical Pictorials," in *Proceedings of Interface 93*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 187–192.

Wolff, J. S., and Wogalter, M. S. (1998), "Comprehension of Pictorial Symbols: Effects of Context and Test Method," *Human Factors*, Vol. 40, pp. 173–186.

Young, S. L. (1991), "Increasing the Noticeability of Warnings: Effects of Pictorial, Color, Signal Icon and Border," *Proceedings of the Human Factors Society*, Vol. 34, pp. 580–584.

Young, S. L., and Lovvoll, D. R. (1999), "Intermediate Processing: Assessment of Eye Movement, Subjective Response and Memory," in *Warnings and Risk Communication*, M. S. Wogalter, D. M. DeJoy, and K. R. Laughery, Eds., Taylor and Francis, London, pp. 27–51.

Young, S. L., and Wogalter, M. S. (1990), "Comprehension and Memory of Instruction Manual Warnings: Conspicuous Print and Pictorial Icons," *Human Factors*, Vol. 32, pp. 637–649.

Young, S. L., Martin, E. G., and Wogalter, M.S. (1989), "Gender Differences in Consumer Product Hazard Perceptions," in *Proceedings of Interface 89*, Human Factors and Ergonomics Society, Santa Monica, CA, pp. 73–78.

Young, S. L., Brelsford, J. W., and Wogalter, M. S. (1990), "Judgments of Hazard, Risk and Danger: Do They Differ?" *Proceedings of the Human Factors Society*, Vol. 34, pp. 503–507.

Young, S. L., Wogalter, J. S., and Brelsford, J. D. (1992), "Relative Contribution of Likelihood and Severity of Injury to Risk Perceptions," *Proceedings of the Human Factors Society*, Vol. 36, pp. 1014–1018.

Young, S. L., Wogalter, M. S., Laughery, K. R., Magurno, A., and Lovvoll, D. (1995), "Relative Order and Space Allocation of Message Components in Hazard Warning Signs," *Proceedings of the Human Factors and Ergonomics Society*, Vol. 39, pp. 969–973.

Zwaga, H. J. G., and Easterby, R. S. (1984), "Developing Effective Symbols or Public Information," in *Information Design: The Design and Evaluation of Signs and Printed Material*, R.S. Easterby and H.J.G. Zwaga, Eds., Wiley, New York.