
Warnings

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1 INTRODUCTION

Safety communications, such as warnings, are used to inform people about hazards and to provide instructions so as to avoid or minimize undesirable consequences. Warnings may be used to address environmental hazards as well as hazards associated with the use of products. Regulations, standards and guidelines have been developed, on to when and how to warn.

Professionals in Human Factors/Ergonomics (HF/E) have played a major role in warnings research conducted in the past three decades, resulting in a substantial increase in technical and scientific literature on the topic (Laughery *et al.* 1994; Edworthy and Adams 1996; Laughery and Wogalter 1997; Miller and Lehto 2001; Wogalter *et al.* 2001). In this chapter, major concepts and findings regarding factors that influence warning effectiveness are reviewed.

In general, product manufacturers and employers are responsible for providing safe products and safe working environments. To manage this responsibility, they should undertake a hazard analysis (e.g. fault tree, failure modes, critical incident) to determine what hazards may occur in foreseeable use and misuse. Once hazards are identified, the next step is to determine how the hazards can be controlled. The classic hazard-control hierarchy defines a sequence of strategies in order of preference for dealing with hazards. The first is to eliminate the hazard through alternative design. The second choice is guarding to separate people from the hazard. However, hazard elimination and guarding are not always feasible. In such cases, warnings are used. Warnings are the third priority choice because they are not always reliable. Persons at risk may not see or hear a warning, may not understand it, may not believe it, or may not be motivated to comply with it.

2 PURPOSES AND METHODS OF WARNINGS

Warnings have several purposes. First, warnings are a method for communicating important safety or safety-related information to a target audience who can then make better, more informed decisions regarding safety issues. This purpose concerns people's right to know, i.e. to

be informed about safety problems confronting them. Second, warnings are ultimately intended to reduce or prevent health problems, workplace accidents, personal injury, and property damage. To accomplish this, warnings are intended to influence or modify people's behavior in ways that will improve safety. Third, warnings may serve as a reminder, to call into awareness the hazard that may be otherwise latent in the long-term memory.

How to warn. There are many kinds of warnings. Warnings can be in the form of signs, labels, package inserts, manuals, tags, audio and video tapes, face-to-face verbal statements, and so forth. Printed warnings are generally text and graphics. Auditory warnings may be verbal and/or nonverbal. In this article, the primary focus is on visual warnings; that is, warning information communicated through the visual modality.

Who to warn. A general principle regarding who should be warned is that it includes everyone who may be exposed to the hazard (i.e. at risk) and everyone who may be able to do something about it. Warnings may be directed to a very specific audience. For example, warnings about toxic shock syndrome from the use of tampons would be directed primarily to women of child-bearing age. Other warnings may be intended for the general public, such as consumer appliances concerning electric shock. While warnings are typically directed at end users, they may also be directed at intermediaries such as physicians who prescribe medications, job supervisors who make decisions about workplace safety, and caretakers of children. Warning design should take into account the lower-level abilities of the target population.

When and where to warn. Warnings should be available when and where they are needed. Generally, the preferred location for a product warning is on the product, but this location may not always be possible. For example, space constraints may impose limits. Alternatives are described later.

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

The communication-human information processing (C-HIP) model (Wogalter *et al.* 1999) is a framework showing

stages of information flow from a source to a receiver who in turn, may cognitively process the information to produce subsequently compliance behavior. The model is displayed in Figure 1. The conceptual stages of source, channel, and receiver are taken from a very simple communication model. The receiver stage is divided into several human information processing substages prior to compliance behavior. Similar models have been discussed by others (Lehto and Miller 1986; Rogers *et al.* 2000).

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 block the flow from getting to the next stage. If all of the stages are successful, the process ends in behavior (compliance).

The C-HIP model can be useful in describing the factors that influence warning effectiveness. Also, it can help in diagnosing warning inadequacies. Each of the processing stages can produce a bottleneck. If the source issues a warning, it can be ineffective if the transmission channel(s) is poorly matched with the message, the receiver, or the environment. Even if a warning is noticed and attended to, the individual may not understand it. Even if the message is understood, it still might not be believed; and so on.

In addition to the linear processing stages, there are feedback loops from later stages, which can affect earlier stages of processing, as illustrated in Figure 1. For example, when a warning stimulus becomes habituated from

repeated exposures over time, less attention is given to it on subsequent occasions. Here, memory (as part of the comprehension stage) affects an earlier stage, attention. Factors affecting each stage of the C-HIP model are described below (Wogalter *et al.* 1999; Wogalter and Laughery 1996).

4 SOURCE

The source is the initial transmitter of the warning information. The source can be a person or an organization (e.g. company, government). One 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 results of hazard analyses. There are several general principles to guide when to employ a warning:

1. A significant hazard exists.
2. The hazard, consequences and appropriate safe modes of behavior are not known to the persons at risk.
3. The hazards are not open and obvious; that is, the appearance or function of the product or environment does not communicate them.
4. A reminder is needed to assure awareness of the hazard at the proper time.

5 CHANNEL

The channel is the medium and modality in which information is transmitted. Warnings can be presented on product labels, on posters, in brochures, as part of audio-video presentations, given orally, etc. Most commonly, warnings are sent via the visual (text and symbols) and auditory (alarms and voice) modalities as opposed to the other senses. There are exceptions such as an odorant added to propane gas to enable leak detection by the olfactory sense.

Media and modality. There are two basic dimensions of the channel. The first is the media in which the information is embedded, and the second is the sensory modality of the receiver. Research comparing effectiveness of language-based warnings presented visually (text) vs. auditorily (speech) are somewhat conflicting. Longer, more complex messages may be better presented visually and shorter messages auditorily. The auditory modality is generally better for attracting attention. Use of more than one channel is usually better than a single channel which is better than no warning.

Warning system. The idea that a warning is only a sign or a portion of a label is much too narrow a view of how safety information is transmitted. Warning systems may consist of a number of components. For example, a warning system for a multisymptom cold medication may consist of a printed statement on the box, on the bottle, and on an insert. Television advertisements and web sites may also contain warnings. Government agencies and consumer groups often provide safety materials for some products

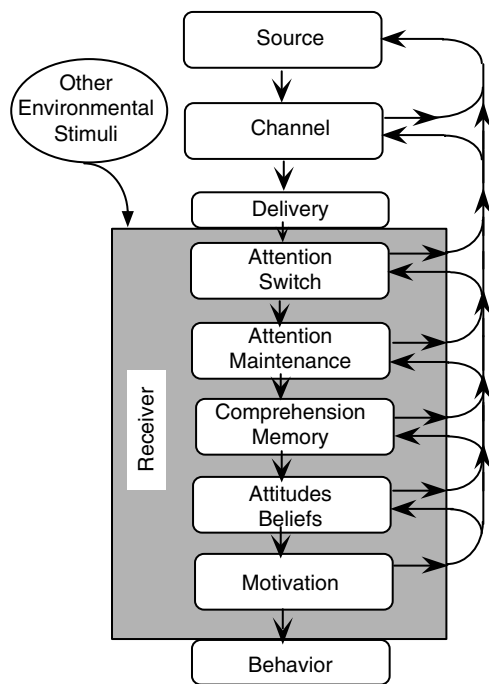


FIGURE 1 Communication-human information processing (C-HIP) model showing a sequence of stages leading to compliance behavior. The model also includes feedback to earlier stages.

or circumstances. 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 containing more information. Different components may be intended for different target audiences (prescribing physicians vs. medication users).

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. Warnings can also be delivered indirectly, such as learning about a hazard during a conversation with a family member. The employer or physician who reads warnings and then verbally communicates the information to employees or patients is also an example. Thus a warning put out by a manufacturer may have utility even if an individual is not directly exposed to that warning.

5.1 DELIVERY

While the source may attempt to disseminate warnings through one or more channels, the warnings might not reach some of the targets at risk. For example, a safety brochure that is developed but not distributed is not helpful. This is another reason for using multiple channels.

6 RECEIVER

The receiver is the person(s) or target audience to whom a warning is directed. For a warning to communicate information and influence behavior effectively, attention must be switched to it and then maintained long enough for the receiver to extract the necessary information. Next, it must be understood, and must concur with the receiver's existing beliefs and attitudes. Finally, the warning must motivate the receiver to perform the directed behavior. The next several sections are organized around these information processing stages.

6.1 ATTENTION SWITCH

An effective warning must initially attract attention. To do so, it needs to be sufficiently salient (conspicuous or prominent). Warnings typically have to compete with other stimuli for attention. Several design factors influence how well they compete.

Bigger is generally better, although what matters is usually its size relative to other displayed information. A bold warning on a product label where there are no other items in larger print is more conspicuous than the same warning on a label where other items are larger. For some products, available surface area is limited, such as small pharmaceutical containers. Potential solutions include tags or peel-off labels. Another method is to put some minimum

critical information on a primary label and direct the user to an accessible secondary source, such as an owner's manual or package insert. Color, of course, can facilitate attracting attention, as can pictorial symbols.

With regard to attention, warnings should be located close to the hazard, both physically and in time. A warning on the battery of a car regarding a hydrogen gas explosion hazard when jump starting is much more likely to be effective than a warning in the car owner's manual. In general, placement directly on the product is preferred.

A related issue is that repeated and long-term exposure to a warning may result in a loss of the ability to capture attention. Habituation can occur even with well-designed warnings. Where feasible, changing the appearance can slow the habituation process.

6.2 ATTENTION MAINTENANCE

Individuals may notice the presence of a warning but not stop to examine it. Attention must be maintained on the message long enough to extract meaning from the material; that is, the information is encoded or assimilated with existing knowledge in memory. With brief warnings the message information may be acquired very quickly, sometimes as fast as a glance. For longer warnings to maintain attention, they need to have qualities that generate interest and not require excessive effort. Some of the same design features that facilitate attention switch (described above) also help to maintain attention. For example, large print not only attracts attention, but also increases legibility, making reading less effortful and more likely.

People will more probably maintain attention if a warning is "readable" with respect to layout. Visual warnings formatted with plenty of white space and coherent information groupings are more likely to hold attention than a single chunk of dense text.

6.3 COMPREHENSION

Comprehension concerns understanding the meaning of the warning. Comprehension may derive from several sources: subjective understanding, such as its hazard connotation, more direct understanding of the language and the symbols used, and an individual's background knowledge.

Signal words and color. Signal words, DANGER, WARNING, or CAUTION, are terms to denote decreasing levels of hazard. Figure 2 shows the three signal word panels for hazards. According to ANSI Z535, the DANGER panel should be used when serious injury or death *will* occur if the directive is not followed. A WARNING panel is used when serious injury or death *may* occur. The CAUTION panel is used when less severe personal injuries or property damage may occur. While CAUTION and WARNING are defined differently by the standard, people do not readily distinguish between them.



FIGURE 2 ANSI Z535 signal word panels. The colors tied to DANGER, WARNING, and CAUTION are red, orange, and yellow, respectively.

According to ANSI Z535, the signal words DANGER, WARNING, and CAUTION are associated with specific colors: red, orange, and yellow, respectively. This assignment provides redundancy. Similar to the terms themselves, the colors orange and yellow do not have a distinguishable hazard connotation. The signal word panels also contain the alert symbol (triangle/exclamation point).

Competence. The level or levels of knowledge and understanding of the audience must be taken into account. Three cognitive characteristics of receivers are important: technical knowledge, language, and reading ability. The hazards of medications and chemicals are often technical in nature, and if the target audience does not have the relevant competence, then the warning may fail.

In a geographic area subgroups in the population may speak and read languages different to the majority. Similarly, increasing international travel and trade and the need to cross language barriers are also issues with respect to warning comprehension. Potential solutions might involve multiple languages and graphic symbols.

Unfortunately, high-level reading skills are often necessary to read warnings intended for people with lower reading abilities. In general, reading level should be as low as feasible. For the general population, the reading level should probably be approximately the skill level of grades 4 to 6 range (expected ability of 10- to 12-year-old readers).

Message content. Figure 3 shows the basic elements of a typical consumer product warning label according to ANSI Z535-4. The content of the warning message should include information about the hazard, the potential consequences of the hazard, and instructions on how to avoid the hazard:

1. *Hazard information.* The warning should tell what the safety problem is. There are exceptions when the

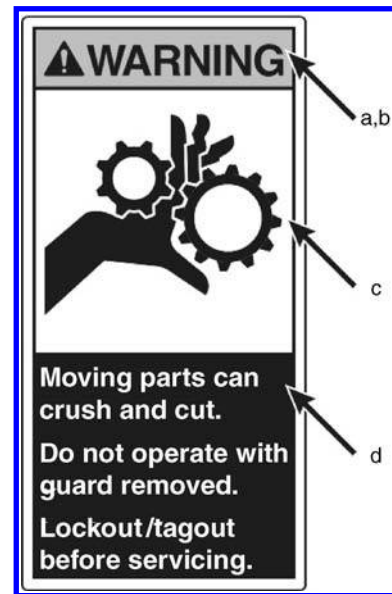


FIGURE 3 The elements of a typical Z535.4 formatted safety label. (a) Signal word and safety alert symbol defines the level of hazard seriousness. (b) The colored background of the signal word panel also serves to identify the level of hazard seriousness. (c) The optional symbol defines the nature of the hazard or the consequence of interaction with the hazard, or how to avoid the hazard. (d) The word message typically communicates the nature of the hazard, the consequence of interaction with the hazard, and how to avoid the hazard.

hazard is: (a) general knowledge, (b) known from previous experience, or (c) “open and obvious,” i.e. apparent to the target audience.

2. *Consequences.* Consequence information concerns what could result. Sometimes, it is not necessary to state the consequences. For example, a sign indicating “Slippery floor” probably does not need to include a consequence statement “You could fall,” as that can be inferred. However, one should be cautious in omitting consequence information, because people may not make the correct inference. A common shortcoming of warnings is that consequences information is not explicit, i.e. lacking important specific details. The statement “May be hazardous to your health” in the context of a toxic vapor hazard is insufficient because it does not tell whether one might have a minor cough or some other more severe outcome (e.g. permanent lung damage). Awareness of severe consequences can be a motivational factor for compliance behavior.
3. *Instructions.* Warnings should instruct people about what to do or not do. Similar to the other statements, the instructions should be specific,

stating exactly what should be done or avoided. A classic nonexplicit warning statement is “Use with adequate ventilation.” Does this statement mean open a window, use a fan, or something more technical in terms of volume of air flow per unit time?

4. *Pictorial symbols.* Safety symbols are used to communicate hazard-related information, often in conjunction with the printed text message. They can contribute to understanding when illiterates or nonreaders of the primary language are part of the target audience. Well-designed symbols can cue large amounts of knowledge quickly.

Habituation. Repeated exposure to a warning over time may result in its being less effective in attracting attention. Warnings with conspicuous features are more likely to reduce the rapidity of the habituation process. Another potential solution is to vary the warnings from time to time, if feasible.

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. This is the distinction between awareness and knowledge. People may have information or experience in their overall knowledge base, but at a given time, it is not part of what they are thinking about. A warning’s presence may cue information in long-term memory so as to bring forth related, previously dormant knowledge into conscious awareness. There are several circumstances in which reminders may be useful:

1. A hazardous situation or product is encountered infrequently, and forgetting may be a factor.
2. Distractions occur during the performance of a task or the use of a product.
3. Heavy task loads exceed attentional capacity to access related knowledge (high mental workload and task involvement).

Technical information. Many warnings require an appreciation of technical information for full and complete understanding of the material. The chemical content of a toxic material, the maximum safe level of a substance in the atmosphere in parts per million (ppm), and the biological reaction to exposure to a substance are examples. 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 not necessary for 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, they need 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.

6.4 BELIEFS AND ATTITUDES

Beliefs and attitudes refer to an individual’s knowledge that is accepted as true, even if some of it may be incorrect. For example, people’s experiences with a situation or product can result in beliefs that underestimate hazard. According to the C-HIP model, a warning will be successfully processed at this stage if the message concurs with the receiver’s current beliefs and attitudes. However, if the warning information does not concur, the beliefs and attitudes must be altered. Therefore, the message must be persuasive to override preexisting incorrect beliefs to be successful.

Hazard perception. One important factor is hazard perception with respect to a situation or product. The greater the perceived hazard, the more responsive people will be to warnings. Persons who do not perceive a product as being hazardous are less likely to look for or read a warning. Perceived hazard is also closely tied to the expected injury’s severity level. The greater the potential injury, the more hazardous the product is perceived.

Familiarity. Familiarity beliefs are formed from past similar experiences stored in memory. A person believing that they are adequately familiar with a product might assume that a similar product operates the same way (which may not be true), reducing the likelihood that he or she will look for or read a warning. 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 how to avoid them. Second, greater use also tends to increase exposure to warnings which increases the opportunity to be influenced by them.

6.5 MOTIVATION

Motivation energizes the individual to carry out an activity. Some of the main factors, which can influence motivation, are discussed below.

Cost of compliance and severity of injury. Compliance generally requires that people take some action and usually there are costs associated with so doing. The costs of complying may include time, effort, or even money to carry out the behavior. When people perceive the costs of compliance to be greater than the benefits, they are less likely to perform the safety behavior. This problem is commonly encountered in warnings with instructions that are inconvenient, difficult, or occasionally impossible to carry out. One way to reduce cost 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. A general rule is that the directed behavior should be as simple, easy, and convenient as possible. The costs of noncompliance can also exert a powerful influence on compliance motivation. Severity of consequences is closely tied to hazard perception and people’s reported willingness to comply with warnings.

Social influence and stress. Another motivator of warning compliance is social influence. When people see others comply with a warning, they are more likely to comply themselves. Similarly, seeing others not comply, lessens the likelihood of compliance.

6.6 BEHAVIOR

The last stage of the process is for individuals to carry out the warning-directed safe behavior. Behavior is one of the most important measures of warning effectiveness. Warnings can change behavior, although not always, as there could be processing failures at the previous stages. Contemporary compliance research has focused on the factors that affect compliance likelihood, not just simply whether compliance behavior occurs or not. Some researchers have used intentions to comply because of the difficulty in measuring behavior under certain conditions. The reasons include: (1) researchers cannot expose participants to real risks because of ethical and safety concerns; (2) events that could lead to injury are relatively rare; (3) the construction scenario must appear to have a believable risk, yet at the same time must actually be safe; (4) there is cost involved in running such research in terms of time and effort. Nevertheless, compliance is an important criterion in determining which warning methods work better than others.

6.7 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.

The basic C-HIP model can be a valuable tool in developing and evaluating warnings. Identifying potential processing bottlenecks can help to determine why a warning may not be successful. The model, in conjunction with empirical data, can identify specific deficiencies and where they occur in the warning system. By using methods that address each stage of the model, one can determine where the break in the chain occurs. By using the model as an investigative tool, one can determine the specific causes of a warning's failure and not waste resources trying to fix the wrong aspect of the warning design.

6.8 DEMOGRAPHIC FACTORS

The above sections have provided a review of the major concepts and findings organized on the basis of the C-HIP model. Demographic characteristics of receivers also influence warning processing and should be considered in warning design. Some research suggests women are more likely

than men to look for, read, and comply with warnings. Research also suggests that persons older than 40 are more likely to take precautions in response to warnings, but they also have more difficulties reading small print on product labels and comprehending symbols. These gender and age effects are not as robust as most other factors, but they should be taken into account.

7 SUMMARY AND CONCLUSIONS

In concluding, several overall principles of warnings are summarized. As a general rule, warnings should be as brief as possible. Two separate statements should not be included if one will do. Longer warnings or those with nonessential information are less likely to be read. At the same time, important information should not be omitted. The brevity criterion conflicts to some extent with the explicitness criterion. Being explicit about every hazard could result in very long warnings. A way to find a happy medium between brevity and completeness relates to prioritization.

Prioritization concerns what hazards to warn about and emphasizes when multiple hazards exist. Among priority decisions are what to include and delete, how to sequence items, and how much relative emphasis to give them. As a general rule, unknown and important hazards leading to more severe consequences and those more likely to occur should have higher priority than less severe or less likely hazards.

Another principle is to know the targeted receiver population by gathering information and data about relevant receiver characteristics. There is usually variability in the target population in terms of competence, experience, and knowledge levels. In such cases, design the warning for the low-end extreme not for the average person. 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 different subgroups.

The durability principle means that warnings should be designed to last as long as they are needed. Where warnings are exposed to weather and abrasion use materials to ensure durability. Information on how to obtain replacement warnings should be given.

In addition to considering warning design guidelines, 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 formal assessments involving larger numbers of people giving independent evaluations. The sample should be representative of the target audience. Studies carried out to evaluate the potential effectiveness of a warning must, of course, incorporate appropriate principles of research design, such as avoiding confounding by extraneous variables, and guarding against contamination by expected outcomes.

The purposes of warnings 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 are communicated to a broad spectrum of people. The use of various media/modalities (channels) and an understanding of the characteristics of the receivers are important in the design of effective warning systems. The design of warnings should be viewed as an integral part of overall systems design. Too often it is carried out after the environment or product design is essentially completed, as an afterthought. Importantly, warnings should not be expected to serve as a cure for bad design.

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