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USING WARNINGS TO INCREASE SAFE BEHAVIOR: A PROCESS MODEL APPROACH

Put simply, the goal of warnings is to reduce accidents and injuries. Warnings are one of several methods used to defend people, and in some cases, equipment, against harm. The first and best defense against accidents and injury is to remove or design out the hazard so that users are not exposed to the danger. Substituting a safe chemical for one known to cause injury is one example of hazard removal.

For some equipment, environments, and jobs, however, there is no practical and functional way to remove all hazards. When hazards cannot be removed, the next defense against accidents and injury is to guard against them. For example, many lawn mowers have so-called "dead man" switches that automatically shut down the power to the blade when the handle is released. This is a procedural guard. Also, many lawn mowers have a shield that drags on the ground behind the mower to prevent debris from flying out in the operator's direction. This is an equipment guard.

While many potential safety hazards can be avoided through proper design and/or guarding, there are still many kinds of equipment, environments, and jobs for which hazards cannot be eliminated. In such cases, the next line of defense against hazards is to educate and train employees. While proper training can ensure that employees learn about hazards and the ways to avoid them (1), this, too, may not be possible or practical. This is true for many small companies and is particularly true for consumer products, where manufacturers have almost no direct control over the behavior of the purchaser after the sale. In these cases, hazard control must be accomplished through warnings, the final line of defense against accidents and injuries.

Warnings are similar in several ways to educational and training programs. Both should communicate what the hazards are and how to avoid them. Both can serve in combination with other methods as an additional (redundant) control; as a reminder to persons who already "know" about the hazard; and to prevent misuse of products and equipment. By themselves, warnings are the least desirable method to control against accidents and injury, primarily because they are the least reliable. People may not see them, read them, understand them, and/or be motivated to comply with them. Therefore, warnings should be considered as a last line of defense and not as a replacement for good design, guarding, and training.

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Process Model of Warnings

Given that warnings are often necessary to communicate hazard information — but are usually not 100 percent reliable — how can they be designed to maximize their effectiveness? Warnings are most effective when they are designed to match the abilities of the target audience to whom the warnings are directed (2). In designing warnings, it is necessary to consider: the abilities and limitations of people; their expectations and motivations; and the system and environment in which the warning is placed.

In recent years, research has revealed some important factors that influence the effectiveness of warnings. Much of the research can be organized into coherent units by us-

ing models of human information processing which divide people's mental processes into a series of stages. Figure 1 shows a fairly simple model of human information processing that can describe the factors that influence the effectiveness of warnings. It also explains how a warning message might fail to achieve the primary goal of warnings, that is, to change people's behavior. As the figure shows, before behavioral change can occur, processing of the warning must pass successfully through three stages.

Initially the warning must capture attention (be seen or heard). Then, the message contained in the warning must be comprehended, and, finally, the message must motivate the user to comply and perform the appropriate behaviors. Because this model proceeds in a temporal sequence, it shows that there are potential "bottlenecks" that could prevent the completion of the process.

If the warning is not noticed in the first place, the information in the warning will not pass to any subsequent stages of processing, and of course, behavior will not be changed. Even if the warning captures attention, it may not be effective if the message is not understood by the user; merely examining and reading the warning does not necessarily mean people understand it. People must comprehend all of the words and the grammar comprising the message, and properly interpret any accompanying symbols and pictorials. And, then even if the warning is noticed and understood, the process will go no further if the warning does not motivate the user to act appropriately. Thus, warnings must also be designed to persuade people to comply.

In summary, the model shows that warnings are processed at various stages. Each stage is a potential bottleneck that could cause processing to stop, and therefore prevent the warning from modifying behavior.

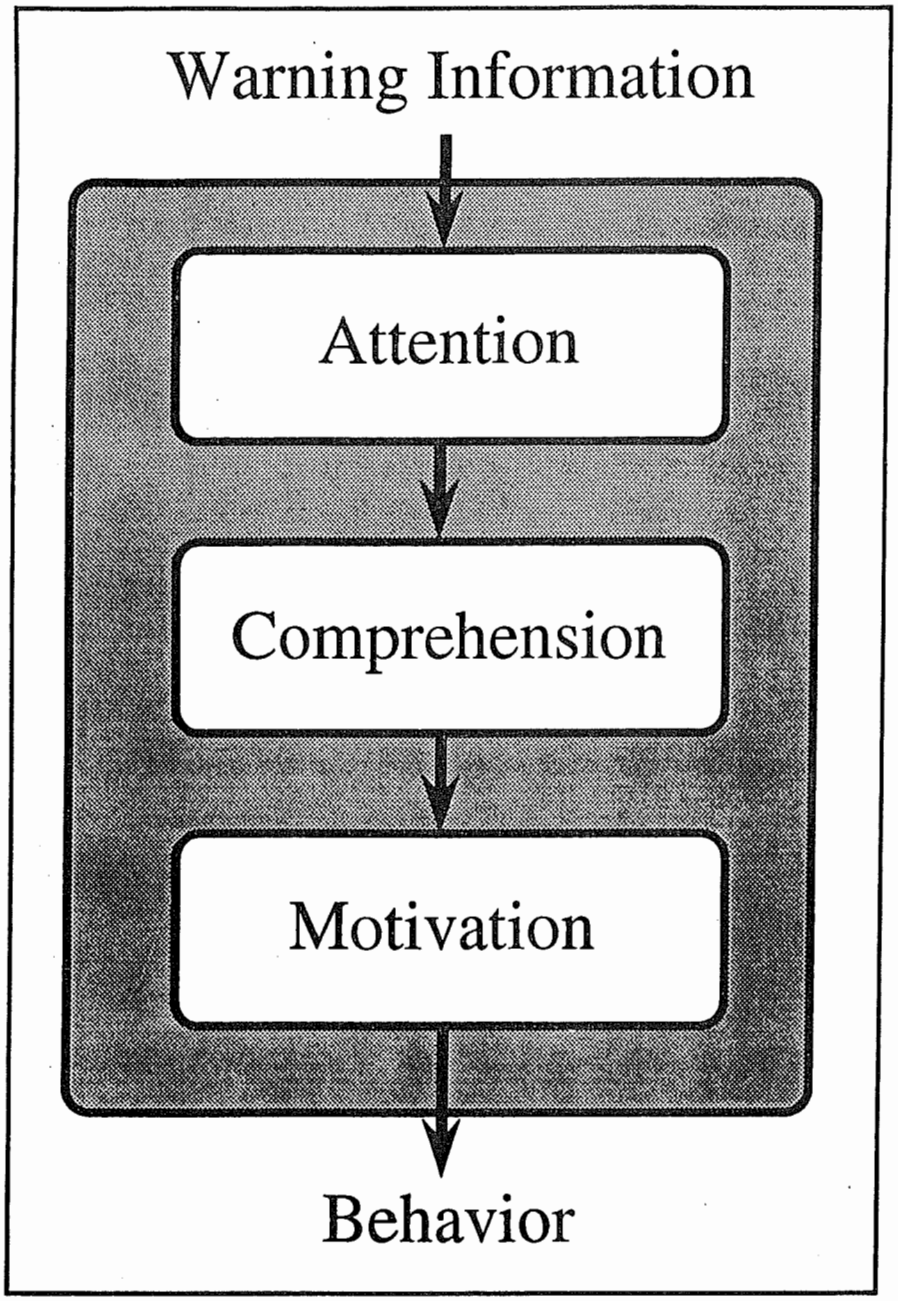

Figure 1. A Model of Human Information Processing of Warnings Leading to Compliance Behavior

Factors Influencing Warning Effectiveness at Each Stage

Most warnings are transmitted via visual (e.g., signs and labels) or auditory (e.g., sirens and bells) channels. Warnings are sometimes communicated through other modalities (e.g., odor added to natural gas to aid detection of leaks, or "stick-shaker" that vibrates aircraft control sticks to warn pilots of an impending stall), but these are less common cases. In the following sections, discussion will be limited to the factors relevant to the visual and verbal modalities. As they have somewhat different characteristics, certain features of warnings that are effective for the visual channel are not appropriate for the auditory channel and vice versa. Features specific to each modality are described in separate sections.

Capturing Attention

Most environments are cluttered and noisy, so for warnings to be seen or heard, they must possess characteristics that help them stand out from the background. In other words, they should be conspicuous or salient relative to the environment in which they are placed (3, 4, 5).

Visual. Well-designed print warnings should have large, bold, and legible typography. The print should be of high contrast relative to its background (dark ink on light background, or vice versa) (3).

In general, visual warnings will be more effective if they are located close to the hazard (e.g., on the product or equipment) rather than further away (e.g., in a separate instruction

manual or on a sign) (4, 6). Similarly, placement in time is important (4). If people are presented with a warning a long time before being exposed to a potential hazard, they may forget the warning. Conversely, if people are presented with a warning too short a time before being exposed to a hazard, they will not have enough time to read and comprehend the message. Also, users need adequate time to read and comprehend the warning before being exposed to the hazard. Thus, warnings should be presented close to hazards in space, and neither too far nor too close in time.

The inclusion of certain kinds of information can also serve to increase the warning's ability to attract attention. These features include: a signal word (e.g., DANGER, CAUTION) (7, 8) that is paired with a signal icon (a triangle enclosing an explanation point) (9, 10, 11); a graphic pictorial (11, 12) of the hazard; the consequences of failing to comply; or instructions concerning what to do or what not to do.

The colors red, orange, and yellow have come to be used in warnings to indicate different levels of hazard (more to less, respectively) (13, 14, 15, 16); however, the choice of color should ultimately depend upon the environment in which the warning is placed (11). A red warning in a room with equipment that is also largely red will not stand out, and thus, it will less likely be noticed. Finally, warnings should have adequate lighting and reflectance properties so that they can be seen in low illumination conditions (3). The above features will identify the visual message as a warning, and alert persons that there is a hazard present.

Auditory. Auditory warnings must be designed to be louder and distinctively different from background noise. One advantage of auditory warnings over visual warnings is their characteristic of "omni-directionality" (17, 18). Auditory signals will spread out in all directions from the source. Thus, persons at risk do not have to be looking in a certain direction (as with a sign or label) to be alerted. Auditory signals also can capture attention while people at risk are performing other, concurrent tasks. Moreover, auditory signals can be useful in calling attention to a nearby visual warning which contains more detailed or specific information. One disadvantage of auditory warnings, however, is that they can annoy people when the signal is set off inappropriately (false alarms).

Target Audience. The target audience of particular concern is persons whose sensory capabilities are more limited than those of the general population. If people with vision or hearing deficits (e.g., the elderly) are expected to be part of the target audience, they should be considered in the design of the warning. One way this can be done is by making visual signals larger, or auditory signals louder (2). To increase the likelihood that the warning will be received, it should be presented redundantly in both the auditory and visual modalities whenever practical and/or possible (17, 18). Redundant presentation also has the advantage of capturing attention when the target persons may be occupied with other tasks that monopolize one modality but not the other.

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Comprehension

If the warning succeeds at capturing attention, the next important processing stage concerns comprehension of the warning's message.

Visual. If the target audience includes persons who do not have high levels of language ability (including children, the less educated, the non-English-reading, etc.), then complex verbal messages may not be understood. To control for this, a good starting point in the design of warnings is to use brief, simple terms. Safety communications should *not* be written at the level of the average person in the target audience, because this may exclude approximately 50 percent of the people. Instead, warnings should be written to reach the lowest practical level of the target audience (2).

Another warning design principle relevant to comprehension is explicitness; that is, warnings should contain specific information (19). Warnings such as, "May Be Hazardous to Health" or "Use in a Well-Ventilated Area," are too vague to relay much usable or practical information. More specific messages, such as "Can Cause Lung Disease" or "Use in a Room with Forced Air or with at Least 2 Open Windows," tell what the particular problem is or what the necessary conditions are for use, and are thus much more effective.

Pictorials which illustrate the hazard or show a simple depiction of the potential consequences, can be a useful way of increasing understanding. Often contained within a circle (to indicate acceptable behavior) or in a circle with a slash through it (to indicate unacceptable behavior), well-designed pictorials can communicate large amounts of information at a glance and can be useful in reaching persons who cannot read a printed verbal message, either because of vision problems (e.g., the elderly) or because they do not possess good knowledge of the language (e.g., foreigners, illiterates, the less educated, children) (14, 20, 21).

Auditory. The ability to understand an auditory message depends upon whether the signal is nonverbal (sirens, tones, bells) or verbal (speech/voice). Nonverbal auditory warnings can be further subdivided into simple and complex. Simple nonverbal auditory warnings usually are used to alert people to a generic problem for which further investigation (often in the visual modality) is necessary to determine the cause (3, 22, 23).

Complex nonverbal signals convey specific hazards by using different temporal patterns or frequencies of sounds to indicate different hazards. While complex nonverbal auditory warnings can relay more information than simple auditory warnings, they are not useful unless the hearer has learned the code. Therefore, some kind of advance training must be given so that complex auditory messages can be deciphered. In addi-

tion, only a limited number of complex nonverbal signals should be used, or it would be difficult to discriminate among the sounds and to remember them all (24, 25). Also, since many kinds of hazards and their associated warnings occur infrequently, periodic retraining and practice procedures are necessary to ensure that the meanings of the different auditory signals are not forgotten (26).

Complex messages can also be transmitted via verbal (speech) warnings. Previously, voice warnings were used only as a personal admonishment (e.g., by mothers to children, supervisors to employees) or through mass-media broadcasts or recordings. In recent years, however, newly developed voice generation chips and digitized sound processors have made voice warnings more feasible. Moreover, recent research indicates that voice warnings can transmit information more effectively than printed signs (17, 18). Unlike complex nonverbal auditory warnings, voice warnings can be understood with little or no prior training, because they take advantage of people's extensive, preexisting verbal capabilities. Thus, the variety of messages that voice warnings can convey is virtually unlimited. Even these messages, however, should be brief and intelligible.

But voice warnings also have inherent problems. For example, speech messages take longer to transmit than simple auditory warnings. As a rule, voice warnings should be even more concise and less complex than print warnings. Only one voice warning can be presented at any one time, as simultaneous presentation can be confusing and exceed people's short-term memory limitations.

Some of these disadvantages can be overcome by: (a) making the different voice messages discriminable from each other (male vs. female vs. synthetic voice); (b) prioritizing the order of the messages; and/or (c) combining a concise voice warning and a more complex print warning (17, 18). In the latter case, the voice warning serves to capture attention, to concisely present the most important information, and to orient the listener to a more detailed printed warning.

Target Audience. Warnings must be structured so that they will be understood by the target audience. The only sure way to determine this is to test the warning on a representative sample of the target audience (4, 20). This testing usually involves presenting the warning and then asking the testing sample what the warning means. If some people do not understand the message (or worse, misunderstand it), the warning should be redesigned and tested again. An illustration of a warning which has been misunderstood is the phrase "low birth weight" that appears in some cigarette warnings. While this message is intended to warn pregnant women that smoking may cause their babies to be born prematurely or underweight, some women have interpreted this phrase to mean that smoking can help keep their *own* weight down during the late stages of pregnancy.

As mentioned earlier, well-designed pictorials have the potential to communicate large amounts of information at a glance. Unfortunately, however, it is also true that poorly designed pictorials may communicate nothing (other than perhaps that a warning is present) (20, 21). Also, like verbal warnings, pictorials can be misinterpreted.

Consider a pictorial that was used with warnings for ACUTANE®, a drug for severe acne that also causes severe 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 surround. The intended meaning of the pictorial is that women should not take the drug if they are pregnant or, if they are not pregnant, to refrain from getting pregnant. However, some women have incorrectly interpreted the pictorial to mean that the chemical might help them to avoid getting pregnant. Again testing a representative sample of the target audience, in this case women of childbearing age, will indicate whether the warning is understood properly. In addition, input from the testing group can be used to generate ideas for alternative designs.

Recent research indicates that voice warnings can transmit information more effectively than printed signs. Unlike complex nonverbal auditory warnings, voice warnings can be understood with little or no prior training, because they take advantage of people's extensive, preexisting verbal capabilities.

Motivation

Once a warning is noticed, read, and understood, it must then motivate people to comply. One of the critical determinants of compliance with warnings is the concept of "cost," which can be defined in two ways: cost of compliance and cost of noncompliance. Usually, people are motivated to comply with a warning because of the potential negative consequences (cost) associated with noncompliance. These include physical injury to themselves and/or others, property damage, or monetary loss. In an industrial setting (or other controlled environment), the cost of noncompliance also can include fines or penalties levied by supervisors or government agencies for unsafe behaviors. It seems reasonable that people would want to avoid injury and loss, and yet they sometimes do not comply with warnings designed to help them avoid such losses. It hardly seems rational that people would willingly subject themselves to potential harm unless there was a reason.

The most likely "reason" is the cost associated with compliance. Compliance with warnings requires people to take some action in response to the warning message. These actions can involve the expense (cost) of time, effort, and/or money. If people perceive that there is a cost of compliance and/or a benefit of noncompliance, the likelihood of them obeying the warning will be reduced.

Cost of Compliance. Several studies have been conducted on cost of compliance and how it influences the effectiveness of warnings. In one field experiment (4), people's response to a warning posted on a broken door was observed. Instead of using the broken door, the people were asked to use either an adjacent door (low cost), or another set of doors roughly 15 meters away (medium cost), or a third set of doors roughly 60 meters away (high cost). The results showed that the warning was largely obeyed in the low cost condition (94 percent), but it was totally ignored when cost was high (0 percent).

This finding was supported in another study (27) in which people performed a mock chemistry task. People were instructed by a warning to wear a mask and gloves during the procedure. The mask and gloves were located either on the table where subjects performed the task (low cost), or in an adjacent room (high cost). When the mask and gloves were nearby, 73 percent of the people used them as instructed. When the items were located in the adjacent room, however, less than 17 percent used them, even though the participants knew that the items were available in the next room. These studies demonstrate that as cost of compliance increases, the effectiveness of a warning decreases, and that the expenditure of even a minimal amount of time or effort can dissuade a person from complying with a warning.

Cost of Noncompliance. While the cost associated with compliance is a potential hindrance to warning effectiveness, its effects can be counteracted by increasing the cost associated with noncompliance. One of the most effective warnings is the consequence statement, in which people are told of the potential negative outcomes that can result from noncompliance. For this component of warnings to be effective, however, consequence information should be presented using explicit language (19). That is, users should be told exactly (specifically) what can result if they do not comply. In addition to providing the user with a better understanding of the nature of the potential hazard, explicitness gives the user a proper appreciation for the severity of potential injury. Research has shown that perceptions of how severe an injury might be influence worker behavior more than either perceptions of their own familiarity with equipment or statistics about injury frequency (28, 29, 30, 31). People are more likely to comply with warnings that describe the severity of the consequences explicitly.

Consequence information is very important in the domain of consumer products, because manufacturers have virtually no direct control over user behavior after the sale. However, in the area of industrial safety, there can be additional costs. For example, there may be fines or penalties levied by supervisors and government inspectors for unsafe worker behavior. However, fines and penalties are not always given out consistently, and may not be imposed until after an accident occurs.

Still another cost, one of compliance, may also be present in the industrial environment: the common perception that obeying warnings reduces productivity. The perception that supervisors want safety as long as it does not interfere with productivity can potentially reduce the effectiveness of posted warnings in the industrial workplace.

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With these problems in mind, several studies have examined warning effectiveness in the industrial setting. An early study (32) examined the effect of a safety poster that reminded workers to sling chain hooks hung from the ceiling. The posters were designed to reinforce other instructions the workers had been given, as well as to serve as a reminder of that information. The results showed increases in slinging behavior by the workers, especially when they perceived the actions to be relevant and necessary. However, compliance with the posters did not occur in the absence of supervisor reinforcement, possibly because workers perceived that management considered the behavior to be unimportant. When supervisors stressed the importance of working safely, however, the posters had positive effects.

Another study more thoroughly examined the influence of supervisor monitoring and feedback in two different industrial settings (33). In both cases, the role of positive feedback (e.g., praise, recognition, cash bonuses) was used as the primary motivator of safe behavior. Several other studies have examined the role of negative feedback (e.g., reprimands, probation, citations, fines) and have found that this works about as well. In either case, it was the informational nature of the feedback that seemed to promote safe behaviors. Workers realized the importance of these behaviors (both from the standpoint of management and safety) and responded accordingly.

Summary and Implications

This discussion has given a broad overview of some of the most important considerations in the design and implementation of warnings. Several implications can be drawn: (a) warnings should be designed so that they will be noticed and examined; (b) information presented in warnings should be understandable by the intended target population; and (c) warnings should be designed so that they motivate people to comply. The first two issues are very important and are well-researched; both are necessary but not sufficient conditions for warning effectiveness.

Although the last issue, motivation, is as important as the other two, it is the least researched. It is clear that warnings posted in the workplace can steer worker behavior in the desired direction, but it is unlikely to do so if (a) workers feel that compliance with warnings requires time or effort that management does not want them to spend, and (b) there is no active monitoring or feedback of worker behavior. In the first instance, the cost of compliance is too high; and, in the second, the cost associated with noncompliance is too low.

Thus, in addition to attention and comprehension considerations, attention should be given to the factors which affect motivation. The cost of compliance should be minimized as much as possible. This can be done in several ways.

First, workers should be provided with required safety equipment (e.g., hearing and respiration protection) at no (or reduced) cost.

Second, the effort needed to obtain and use safety equipment should be kept to a minimum (4, 27). For example, if hearing protectors are required, they should be made readily available in an area where they are needed.

Finally, the comfort associated with safety requirements must be considered (35). If workers are too uncomfortable wearing safety equipment, then they are less likely to do so.

In addition to these suggestions, the cost of noncompliance must also be considered and maximized. Well-written and explicit warnings can give workers an appreciation of the hazards and consequences associated with noncompliance. Also, feedback on safety performance (both positive and negative) should be given regularly. Together, these suggestions can help reduce the incidence of unsafe worker behavior. □

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