Factors influencing the effectiveness of warnings

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Abstract
Warnings are one of several hazard control methods that can be used to protect people and property against dangers and loss. This article surveys the factors known to influence the effectiveness of warnings. The presentation of this material is organized around a sequence of stages of a human information processing model that begins with the presence of warning information leading to attention, comprehension, beliefs/attitudes, motivation and ends with compliance behavior. Whether a warning is noticed and attended to often depends on whether it is conspicuous relative to other stimuli in the environment. Research showing ways to make warnings conspicuous are described. Given that a warning is noticed and attended to, the message must also be understood in order for the warning to be effective. The message must be tested with a representative sample of the target population in order to ensure comprehension. However, even if the warning is understood, it still might not lead to compliance behavior if the message does not fit with people's existing attitudes and beliefs and is not sufficiently persuasive to change those attitudes and beliefs. Finally, the warning also needs to energize or motivate people to comply with the warning and this will depend on such factors as cost (e.g., time, effort, money) of performing the requested compliance behavior as well as the costs imposed on noncompliance. Implications for practical application and gaps in current knowledge are discussed.

1. Introduction

The basic goal of safety programs and hazard analysis is to prevent accidents and injuries to people and damage to property. Warnings, the topic of this article, are one of several methods that can be used to defend against harmful outcomes. Warnings may be supplied on signs, on labels, in product manuals, and in other forms that will be described later. The principle purpose of warnings is to effectively communicate information about potential hazards and to reduce unsafe behavior that might otherwise occur without their presence. However, warnings are not generally considered the best injury-prevention strategy to use (by themselves) particularly if other more effective methods can be employed instead of, or in addition to, warnings.

Several other hazard prevention methods are generally preferred over warnings if they can be properly incorporated into a product system. Four hazard prevention methods, in their

order of preference, are described here. 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. Another way to completely remove a hazard is to ban a dangerous product from being sold in the first place, or if the product has already been purchased, to issue a product recall. Recall of a product may involve a retrofit design change that removes the hazard or the product might be exchanged with another better-designed version.

However, for some equipment, products, environments and jobs, there is no practical and functional way to remove all of the potential hazards and still have a functional product. One example of this is the common power lawn mower which inherently has mechanical, heat, chemical, and/or electrical hazards. When hazards can not be removed, the next best defense against accidents and injury is to guard against them, or in other words, to place some kind of barrier between people and the hazard. For example, many current lawn mowers have a so-called 'dead man' switch that automatically shuts down the power to the blade when the handle is released. This is a procedural guard that prevents people from coming in contact with the rotating blade by disengaging power to the blade when the operator is anywhere other than positioned near the handle controls. 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. Another example occurs in the construction, maintenance and repair of an underground pipe facilities. When open holes in the ground are present, temporary barriers placed surrounding the openings serve to direct people away from the danger.

While potential accidents can be avoided through proper design and guarding, there are still many kinds of products, equipment, environments and jobs for which the hazards can not be eliminated by these methods. In such cases, the third line of defense against hazards is to educate and train employees and the public who may use or come in contact with the hazard. Proper training can ensure that employees and users know about the hazards and ways to avoid them (Racicot and Wogalter, in press). However, there are many situations where formal education and training 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 purchasers and other potential users after the sale. In these cases, hazard control is often accomplished through warnings.

Warnings are similar in several ways to the other methods mentioned above. The most obvious similarity is with educational and training programs. The use of warnings and educational/training programs are designed with the intent to communicate what the hazards are and how to avoid them. In addition, warnings can also be considered a type of guard that lacks the usual solid physical barrier we often associate with guards. It is a kind of informational guard. Moreover warnings can serve in combination with the 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 preferable method to control against accidents and injury, primarily because they are the least reliable. There are many points at which they might fail. People may not see or attend to them, may not understand them, may not produce the appropriate attitudes and beliefs and/or may not influence people's motivation to comply with them. Therefore, they should be considered as a last line of defense and not as a replacement for good design, guarding, and education/training. The other methods, particularly the first, designing out the hazard, are better methods of hazard control.

As briefly described above, warnings are often necessary to communicate hazard information when other methods can not be used to effectively eliminate potential accidents, personal injury, and property damage. Given this state of affairs and the fact that warnings are not totally reliable, the principle question is: How can warnings be designed to maximize their effectiveness? The remainder of this article addresses this question.

As briefly mentioned earlier, there are two main purposes of warnings. One is to provide information to people who are at risk so that they have an appreciation the hazards. Research has suggested that warnings should contain certain critical elements:

- a signal word such as 'Danger' and 'Caution' that enables people to recognize that the message is a warning and that a hazard is present in the situation as well as the extent or level of the hazard (with 'Danger' signalling more serious and more probable injury than 'Caution');
- a description of what the hazard is, e.g., in the case of a no diving sign, a statement such as 'Shallow water' would provide information about the specific danger involved;
- a description of the consequences that could occur if the person fails to obey the warning's directions or performs other unsafe behaviors, e.g., 'You can be permanently paralyzed';
- the directions or instructions or in other words, the specific things the person should or should not do to avoid the hazard, e.g., 'No diving'.

The four basic elements of warnings described above are probably the minimum acceptable standard. This article will discuss factors that go beyond these components. In addition, despite what has just been stated not all warnings need to have all four of the above mentioned components. These are special cases and how one goes about determining which components are necessary and which are not will be described later when testing methods are discussed. However, at this juncture two examples will be mentioned to illustrate the point. One is a sign for wet floors. The consequences statement 'You may slip and fall' is likely to already be well known by everyone and so it does not add anything new to what people already know. The other example is the common 'Stop' sign. In this warning, there is nothing more than one word telling the instruction of what to do (plus a distinctive eight-sided shape and red color), but once again, the other elements do not have to be printed on the signs as they are already well known (e.g., if you fail to obey, you will be breaking the law and may injure yourself and others, and have increased insurance costs). However except for these and other exceptions, warnings should in general have all four of the components stated above because each is needed to give people an appreciation of the hazards and to make informed decisions. In order for warnings to provide information most effectively they should be designed to match the abilities of the target audience to whom the warnings are directed (Laughery and Brelsford, 1991). 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. More will be said about the information transmission mission of warnings later.

The second major purpose of warnings is to change behavior. In particular, the intent is redirect people away from performing unsafe acts that they might otherwise do without the warning. It has been argued in the warnings literature, that the behavioral purpose of warnings is more important than the informational purpose, because ultimately it is more important to have people avoid the hazard than to know about it and get hurt. For example, it much more important that a child avoid a hazard than it is for them to understand the nature of the hazard. It is for these reasons the importance of warnings' behavioral influences will be emphasized in this article. Nevertheless, both the informational and behavioral purposes of warnings are important. In recent years, a growing body of research has revealed many important factors that influence both aspects.

2. A human information processing model of warning effects

Much of the research on warnings can be organized into coherent units by using a human information processing approach. This formulation divides people's mental processes into a sequence of stages. Figure 1 shows a fairly simple human information processing model that can be useful in organizing the factors that influence the effectiveness of warnings. It also can be used to explain how a warning message might fail to achieve the

previously-mentioned goal of warnings: to inform people about the hazard and to promote safe behavior. As the model shows, before warning-induced effects can occur, and in particular, behavioral change, processing of the warning must successfully pass through several stages.

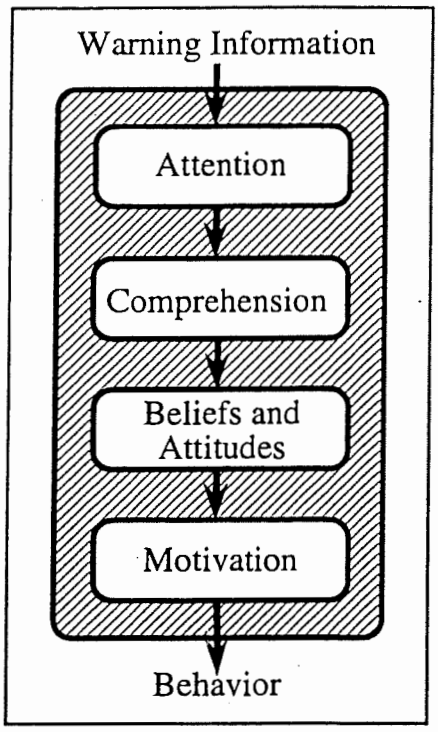

Figure 1 A human information processing model showing a sequence of stages leading to compliance behavior.

Initially the warning must capture attention; that is, it must be noticed. Then, the message contained in the warning must be comprehended. To go further in the process, to affect people's behavior, the warning needs to agree with their existing attitudes and beliefs, and if it does not, it must be adequately persuasive to change them. Finally, the message must motivate the user to comply and perform the appropriate behaviors. The fact that this model proceeds in a temporal sequence shows that there are potential 'bottlenecks' that could prevent the process from being completed. If the warning is not noticed in the first place, the information in the warning will not pass on to any subsequent stages of processing, and of course, behavior will not be changed. But 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 comprehend it. People must understand all of the words and the grammar comprising the message, and properly interpret any accompanying symbols and pictorials. But even if the warning is noticed and understood, the process will go no further if the warning does not adequately influence the person's beliefs and attitudes in the appropriate direction, which can be quite difficult to do if the warning is communicating information that is in opposition to the person's current beliefs and attitudes. Finally, even if the processing of the warning is successful to this point, the warning still will not be behaviorally effective if it does not motivate, or in other words, energize the user to perform the appropriate safe actions.

Thus the human information processing model shows that warning information is processed in a series of stages. Each stage in the sequence is a potential bottleneck that could cause

processing to stop, preventing any further processing of the warning and therefore hindering it from modifying behavior. The following sections describe the factors shown by research to influence warning effectiveness at each stage of the model.

3. Effectiveness factors at each stage

Most warnings are transmitted visually (e.g., signs and labels) or auditorially (e.g., tones and speech) channels. Sometimes hazard information is conveyed via other modalities such through the olfactory sense (e.g., the odor added to natural gas to aid detection of leaks), or kinaesthetic/tactual sense (e.g., a 'stick-shaker' that vibrates aircraft control sticks to warn pilots of an impending stall), but these are unusual cases. In the following sections, discussion will be limited primarily to the factors relevant to the visual modality, with an occasional comment concerning the transmission of warnings through the auditory modality. The visual and auditory senses have somewhat different characteristics, and therefore certain features of warnings that are effective for one channel may not be appropriate for the auditory channel and vice versa. However, most of the differences between these two modalities are restricted to the earlier stages of the model.

3.1 Attention

Most environments are cluttered and noisy, so in order for warnings to be seen (or heard) they must possess characteristics that facilitate their standing out from the background (Wogalter, Kalsher, and Racicot, 1993a). In other words, they should be conspicuous or salient relative to its context (Sanders and McCormick, 1993; Wogalter, Godfrey, Fontenelle, Desaulniers, Rothstein, and Laughery, 1987; Young and Wogalter, 1990).

Print warnings should be of high contrast relative to the background (dark ink on light background, or vice versa) (Sanders and McCormick, 1993). Moreover to facilitate their being noticed, print warnings should have large, legible bold-faced alphanumeric characters. The specific sizes of the printed letters should be based on visual angle (generally at least 5-10 degrees of arc on the retina and greater is preferred) and the distance that the warning is likely to be from the person. Other variables important in determining adequate size include the target population (discussed further below), whether individuals are likely to be moving (and if so, how fast and in what direction), where people are likely to be looking, what the illumination conditions are likely to be, among others.

In general, warnings effectiveness will be facilitated if they are located close to the hazard (e.g., on the product or equipment) than further away (e.g., in a separate instruction manual or on a sign) (Frantz and Rhoades, 1993; Wogalter, Barlow, and Murphy, in press,; Wogalter et al., 1987, 1993a). Similarly, placement in time is important (Frantz and Rhoades, 1993; Wogalter et al., 1987). If the temporal space between warning presentation and exposure to a potential hazard is large, people may not recall the warning. Also, locating warnings too close to the hazard can cause problems in certain circumstances. Users need adequate time to read and comprehend the warning in order to properly react to protect themselves. So, while proximal placement is a generally a good rule to follow, in some cases having the warning too close to the hazard might be dangerous.

The inclusion of certain kinds of information in the warning can also serve to increase its ability to attract attention. These features include: a signal word (e.g., 'Danger', 'Caution') (Chapanis, 1994; Silver, Gammela, Barlow, and Wogalter, 1993; Silver and Wogalter, 1991; Wogalter and Silver, 1990) that is paired with a signal icon (a triangle enclosing an explanation point) (Laughery, Young, Vaubel, and Brelsford, 1993a; Wogalter, Jarrard, and Simpson, 1994b), and a graphic pictorial (e.g., Laughery et al. 1993a; Jaynes and Boles, 1990). The colors red, orange, and yellow are commonly used in warnings to indicate different levels of hazard (from greater to lesser, respectively) (Bresnahan and Bryk, 1975; Chapanis, 1994; Collins, 1983; FMC Corporation, 1985; Westinghouse Electric Corporation,

1981); however, the choice of color should also depend on the environment in which the warning is placed (Young, 1991). A red warning in an environment that is also largely red will not stand out and thus its noticeability will be lower.

There are several kinds of situations where the types of information and features that can be placed on a sign is constrained. Often the reason is due to space limitations (e.g., the product is small having limited surface area to contain the warning, while possessing many kinds of hazards) but also may be due to sign distance to the person and speed of movement (such as in traffic signs). Thus, there are several directions that decisions might go. One is to try to place all the necessary information on the sign or label regardless of the size. Another alternative is to leave out information from the sign or label. This may be an acceptable method if there is a complete set of information that users can readily access (e.g., another sign or label posted elsewhere, a printed instruction sheet or manual that accompanies the product). Some research has shown that a well-located brief persuasive safety directive can be effective in getting users to read a set of longer, more detailed warnings in the accompanying instruction manual (Wogalter et al., in press). Another solution is to increase the size of a product label or sign so that there is more surface area upon which to print either more information or to use a larger font or both (Barlow and Wogalter, 1991; Wogalter, Forbes, and Barlow, 1993c; Wogalter and Young, 1994; Kalsher, Pucci, Wogalter, and Racicot, 1994).

Warnings should have attention-getting properties that allow it to be seen under degraded environmental conditions such as low illumination, smoke, or fog (e.g., Lerner and Collins, 1983). In addition, warnings should be adequately lit (by directed or back-lighting) and/or have good reflectance properties so that they can be seen under reduced-light conditions (Sanders and McCormick, 1993). The presence of these features will help to attract people's attention and alert them that the material that they see is a warning and lets them know that a potential hazard is present.

While this chapter is primarily limited to visual warnings, a few comments regarding auditory warnings should be noted because they can sometimes be combined with visual warnings in certain systems. Auditory warnings should be louder and distinctively different from expected background noise. One advantage of auditory warnings over visual warnings is the characteristic of omnidirectionality (Wogalter et al., 1993a; Wogalter and Young, 1991). Auditory signals tend to spread out in all directions from the source. Thus, persons at risk do not have to be looking at a particular location to be alerted (as with a sign or label). Another advantage is that auditory signals can capture attention while the persons at risk are performing other concurrent tasks. Auditory warning can be used to call attention to a nearby visual message which contains more detailed or specific information. One disadvantage of auditory warnings in terms of its attention getting effects is that they can annoy people when the signal is set off inappropriately (i.e., false alarms).

An important concern in developing noticeable warnings is persons who have sensory capabilities that are more limited than others in the general population. If individuals with vision or hearing impairments (e.g., the elderly) are expected to be part of the target audience (which is often the case), their capabilities and limitations should be considered when designing the characteristics of the warning, as for example by making the signs or labels larger or the auditory signals louder (Laughery and Brelsford, 1991). To increase the likelihood that safety information will be conveyed to individuals who have sensory deficits, it is particularly important that the features discussed in the above paragraphs be considered in the design. Additionally, another strategy is to present the warning information redundantly in two or more modalities whenever it is practical and/or possible (Wogalter et al., 1993a; Wogalter and Young, 1991). 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.

An important issue with respect to the attention gettingness of warnings is related to a psychological concept called habituation. Upon seeing a warning over time, it will attract less and less attention and eventually may not draw an explicit attention-getting response, despite the fact that the warning has many of the features outlined in the above paragraphs. It is, however, likely that a well-designed warning with many of these features as is practical will become habituated at a slower rate than a warning with fewer of these features. There are also other ways to slow down or counteract habituation. The primary method to accomplish this is stimulus change. Stimulus change can be achieved by modifying the characteristics of an existing warning so that it looks or sounds different. Technology has also provided some new ways to counteract habituation. One is to electronically control warning exposure so that it is presented only when it is needed (e.g., during the time at which the risky behavior might be performed). Electronic presentation can also enable personalization of the sign (e.g., using the targeted individual's name) and varied presentation patterns (partial, irregular, reinforcement) that will avoid or delay habituation (Racicot and Wogalter, in press; Wogalter, Racicot, Kalsher, and Simpson, 1994a).

Another potentially useful method to counteract habituation, as well as to capture attention more generally, is to use interactive warnings. These warnings require that individuals interact in some way with the warning while performing a task. Interactive warnings require some sort of overt physical manipulation by the individual (such as moving the warning in order to use a piece of equipment). Theoretically, interactive warnings serve to break into the habitual performance of a familiar task (i.e., interrupting a well-learned behavioral script), causing the individual to attend to the warning. Over time any particular interactive warning will become habituated, but due to its nature, interactive warnings are likely to slow down the process (Duffy, Kalsher, and Wogalter, in press; Frantz and Rhoades, 1993; Wogalter et al., in press, but also see, Hunn and Dingus, 1992).

Directly tied to the habituation issue is a related consideration that has not been adequately addressed in the warning's literature regarding the costs versus benefits of standardization. There has been an increasing push for the development of standards for warning design. There are number of positive aspects for standardization (e.g., people will know that the sign or label is a warning when they see it). However, standards will promote similarity in appearance which in turn is likely to facilitate habituation-type problems. That is, having a standard look conflicts with countermeasures to prevent or slow down habituation. Clearly, this is an important tradeoff that should be addressed by warning designers and researchers. In a different and perhaps less obvious sense, the habituated condition can be an indication that the information is already well known. In other words, habituation means that person have been exposed to the material, has looked at it, and any subsequent failure to look a the material is due to the fact that the individual has memory of that information (and as a consequence does not need to look at the material any longer). Returning to the standardization issue, if all signs or labels have the same style, then changes made only to the content may not be noticed, individuals may think that they know the information because it looks similar to what they have been exposed to previously.

Lastly, in order to assure that the warning is attention getting, it is important that it is tested with a representative sample of the target population of potential users. Evaluation may take many forms such as:

- having these individuals give numerical ratings of various potential warning designs;
- having them take part in legibility evaluations in which different designs are presented at varied distances and under degraded conditions;
- measuring their reaction time to displays with and without a warning;
- assessing memory to the signs (which if they remember the sign after being exposed to it then it indicates that they must have looked at it at some point);
- recording whether they look at the warning, as well as how quickly and how long they look at it.

The best evaluations are ones that most closely replicate the conditions and tasks under

which the target individuals are likely to be at risk. Thus, measurement of looking behavior in the actual environment where the sign is to be placed with a hidden video camera is a more valid assessment of attention-gettingness of a warning than subjective preference ratings of warnings listed in a questionnaire booklet.

3.2 Comprehension

If the warning captures attention and the individual looks at (or listens to) the warning, then the next important processing stage that must be completed concerns comprehension or understandability of the message. The purpose of having an understandable warning is to give individuals at risk an adequate appreciation of the hazard. Effective understanding of the warning enables people to make informed judgments regarding the risks.

One of the common, but most usually wrong, assumption of individuals who design warnings is that everyone at risk will understand the hazard as well as he or she does. Writers of warnings should never assume this because they are not representative of the target audience, a population which can often have a wide range of mental and physical characteristics. What is 'common-sense' to the designer will not necessarily be 'common sense' to the individuals in the target audience.

Safety communications should *not* be written at the level of the average or median-level percentile person in the target audience because this could exclude approximately 50% of the people below that point from understanding the message. Rather warnings should be written so that they are understandable by the lowest level of the target audience that can practically be reached (Laughery and Brelsford, 1991).

What are some reasonable assumptions that we can make? If the at-risk target audience includes people who do not have high levels of language ability (including children, the less educated, the non-English reader/speaker, etc.), then generally it can be assumed that these individuals will not understand warnings that contain complex verbal messages.
Thus, whenever possible, verbal warnings should be comprised of brief, simple terms. In general, if there are two or more terms or statements that mean the same thing, then the best ones to use in the warning (with all other things being equal) will be the terms that are shorter in length and are more frequently used in the language (i.e., common terms).

In addition, there are some other convenient methods to determine (albeit only approximately) the understandability of textual messages. These include readability formulae that are based on frequency-of-use counts, letter length of words, word length of statements, etc. (though some of the formulae need to be adapted for shorter length, nonpunctuated text, see Silver, Leonard, Ponsi, and Wogalter, 1991). In addition, there are grade-school teacher workbooks that contain terms that are appropriate for different ages (Silver and Wogalter, 1991). Another rough method for determining understandability is to have a sample of the target audience give numerical ratings for various sample messages according to how understandable each is. However, all of the above methods can only serve as an approximate guide to what is possibly appropriate. In other words, the above methods can serve to eliminate poorly written messages, but they will not determine whether people actually understand them. Actual testing of the material using a representative sample of individuals of the target population (as will be described in more detail later) provides the best estimate of how well people will actually comprehend the message.

Another important design principle relevant to warning comprehension is explicitness. Explicit messages contain specific information which will often help people to understand exactly what the hazard is, giving definitive instructions on what they should do or should not do to avoid the hazard, and specifically what the consequences are for not complying (Laughery et al. 1993b). Warnings that state 'Use in a well-ventilated area' or 'May be hazardous to health' do not convey much useful information because they are too vague. More specific messages like 'Use in a room with forced air or with at least two open windows' or 'Can cause lung

cancer which almost always leads to death' are preferred because they tell what the necessary conditions are for use, what the particular problem is, and the consequences.

Pictorials can be another useful way to increase understanding of the hazards. Pictorials are covered more extensively in other papers in the Public Graphics symposium, but some brief mention here is appropriate because they can be a very important component of warnings. Pictorials may be used to illustrate the hazard, the potential consequences, and/or what to do or not do to avoid the hazard. Well-designed pictorials have the ability to communicate large amounts of information in a glance and can be useful in reaching persons who can not read a printed verbal message, either because of vision problems (e.g., the elderly) or because they do not possess good verbal skills or knowledge of a non-native language being used in the warning (e.g., foreign visitors, illiterates, the less educated, children) (Boersema, and Zwaga, 1989; Collins, 1983; Lerner and Collins, 1980, Laux, Mayer, and Thompson, 1989; Zwaga and Easterby, 1984).

Sometimes pictorials are contained within a circle surround (indicating a permitted or recommended situation) and sometimes with a slash through it or an X (indicating prohibition of the depicted situation). However, other surround shapes (e.g., octagon, triangle, rectangle, etc.) are used in various warning systems. Meanings for the shapes are often designated within a given sign systems but with a few exceptions such as the octagon stop sign or perhaps the triangle yield sign in the USA, it is not clear whether people know or even pick up over time the underlying meaning of the shapes without specific training. This state of affairs may, in part, be due to the fact that the surround shapes are often used inconsistently across various sign systems.

A few brief comments regarding the understandability of auditory warnings are worth noting. The understandability of an auditory warnings depends on whether the signal is nonverbal (sirens, tones, bells) or verbal (speech/voice). Nonverbal auditory warnings can be further divided into simple and complex. Simple nonverbal auditory warnings are usually used as alert (attention-getting) signals for generic problems upon which the visual modality can then employed to investigate the cause (Sanders and McCormick, 1993; Eastman Kodak Company, 1983; Sorkin, 1987).

Complex nonverbal signals are composed of sounds of different (sometimes dynamic) amplitude, frequency and temporal patterns for the purpose of communicating different types and different levels of hazards. Complex nonverbal auditory warnings can carry more information than simple auditory warnings, but the listener must know what the code means and so it is important to choose sounds that can be easily associated with the condition being warned about. Therefore some kind of training must be given in advance so that complex auditory messages can be deciphered. Only a limited number of complex nonverbal signals should be used in a particular application, because, otherwise, it will be difficult to discriminate among the sounds and to remember them all (Banks and Boone, 1981; Cooper, 1977). Also, since many kinds of hazards and their associated warnings occur infrequently, over time people may forget what the auditory signal means when it re-occurs after a lengthy period of time following training. Thus, retraining and practice procedures are necessary to ensure that the meanings of the various auditory signals have not been forgotten (Patterson and Milroy, 1980).

Complex warning messages can also be transmitted via voice (speech). Historically, voice warnings have been used for personal admonishments (e.g., by parents to children, supervisors to employees) or through mass-media broadcasts or recordings. However, in recent years, voice chips and digitized sound processors have been developed making voice warnings feasible for a wide range of novel approaches and applications. Moreover, recent research indicates that voice warnings under certain circumstances can be more effective in transmitting information than printed signs (Wogalter et al., 1993a; Wogalter and Young, 1991; but also see Barlow and Wogalter, 1993). Unlike complex nonverbal auditory warnings,

voice warnings require little or no prior training because voice takes advantage of people's preexisting verbal capabilities. Thus, the variety of messages that it can convey is not as limited as the other kinds of auditory signalling methods. To maximize effectiveness, however, the messages should be intelligible and brief.

There are also some inherent problems associated with voice warnings. Time to transmit speech messages requires longer durations compared to simple auditory warnings. Voice warnings should be even more concise and less complex than print warnings; otherwise, people's limited short-term memory may be exceeded. With long complicated voice statements, listeners must hold in memory the early parts of statements to fully understand the latter parts. Complex statements often have low-frequency, less familiar terms and less predictable word orders which can produce a heavy load on working memory. Generally with print warnings, individuals have the opportunity to look over the material once again if their first exposure to the material did not produce clear understanding. In addition, only one voice warning should be presented at any one time as simultaneous presentation can be confusing. Some of the above-mentioned disadvantages of voice warnings can be overcome by:

- making the different voice messages discriminable from each other (male vs. female vs. synthetic voice);
- prioritizing the order of the messages;
- allowing repeats of the message on demand, and/or
- combining a concise voice warning and a more complex print warning (Wogalter et al., 1993a; Wogalter and Young, 1991).

In the latter case, the voice warning can be used to capture attention, to briefly present the most important information, and then to orient the person to a more detailed printed warning.

The characteristics of warnings that enable understanding depend on the target audience. As indicated above the best way, and perhaps the only way, to determine whether the warning will be comprehended is to test it on a representative sample of the target audience to determine if they understand it (Wogalter et al., 1987; Lerner and Collins, 1980). Usually the testing can involve one of several different methods. The best method is an open-ended response method where participants are simply shown the verbal warning or pictorial and asked to tell in an interview format or to write in a questionnaire what it means to them in their own words. The difficulty of this method lies mainly in the scoring of the responses after data collection is completed. Often people do not clearly express what they mean so scoring is partially based on interpreting what the individuals said or wrote. Responses can be scored with a range of criteria from strict to lenient (e.g., see Young and Wogalter, 1990 for a description) and/or judged as completely or partially correct, etc. Having two independent judges score the answers (without knowledge of conditions if it is an experiment) using agreed-upon criteria will provide a measure of scoring reliability.

Other kinds of testing may involve multiple choice or matching tests where the correct responses are mixed together with incorrect (distractor) responses. These methods are not as desirable as the open-ended response method described above because the outcome of people's accuracy is strongly dependent on the quality of distractor answers that are made available. Moreover, these tests are less realistic in the sense that they reflect retrieval operations that are not commonly employed with respect to the kinds of processing that people usually perform with warning signs and labels. Other potential tests include ranking and rating several potential warning elements, but as mentioned earlier these kinds of tests only tell which of the elements may be the better of the group of alternative versions, but do not provide strong categorical evidence on whether the message is truly understandable, that is, whether people will actually understand the warning under realistic conditions.

If the testing shows that some substantial number people do not understand the message, or worse, misunderstand it (i.e., a critical confusion), then this suggests that the warning should be redesigned and tested again. One example illustration of misunderstanding is the phrase 'low birth weight' that appears in some cigarette warnings. This message was originally

intended to admonish pregnant women not to smoke because their babies might be born prematurely, etc. However, some women have interpreted this phrase to indicate that smoking can help keep their weight down at the late stages of pregnancy. Had this phrase been tested with a representative sample of the target population, in this case women of child-bearing age, before it was put on packages, this misinterpretation would likely have been noted, and another better phrase could have been used. Additionally, the procedures for evaluating comprehension can also incorporate the collection of new ideas on how the warning materials can be improved if a new or redesigned warning should be necessary (Wogalter, Wolff, Magurno, and Kohake, 1994b; Wolff and Wogalter, 1993).

As mentioned earlier, well-designed pictorials have the potential to communicate large amounts of information at a glance. However, it is also true that poorly designed pictorials may communicate nothing (other than perhaps that a warning is present) or worse, the wrong message (Lerner and Collins, 1980; Laux et al., 1989). So, like verbal warnings, pictorials can be misinterpreted. Consider a pictorial that accompanied the verbal warnings for Acutane® (Roche Dermatologics, Nutley, NJ), a drug for severe acne that also causes severe tautological effects (birth defects) in babies of women taking the drug just before or 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 take strong precautions against getting pregnant. However, some women have incorrectly interpreted the pictorial to mean that the chemical might help them to avoid getting pregnant. Early testing using a representative sample of the target audience, in this case, women of child-bearing age, would have provided information about this misinterpretation. Also, input from participants can be used generate ideas for new alternative designs (if the testing indicates that redesigns are needed). Any new designs created as a result of input from earlier testing should be tested to ensure that they are understandable (Wogalter et al., 1994b; Wolff and Wogalter, 1993).

In many cases, the testing of verbal and pictorial components of warnings will require several rounds of testing. This iterative redesign and retest process should be continued until an adequate level of comprehension is achieved.

3.3 Beliefs and attitudes

Given that a warning has been attended to and understood, then the next major stage concerns beliefs and attitudes. 'Beliefs' refer individual's knowledge of a topic that is accepted as true (regardless of its actual truth) and which is used to form opinions, expectations, and judgments. 'Attitudes' are similar to beliefs except more emotion or feeling is involved. Because of their similarity, beliefs and attitudes are grouped into one stage for the purposes of the current model. However it should be noted that this was an arbitrary decision as beliefs could have been grouped with the previous stage and attitudes kept separate as an emotional component.

This stage of processing has not garnered as much research as the two earlier stages, but nevertheless, people's beliefs and attitudes can strongly influence whether a warning will be effective. Among the factors that affect warning processing at this stage include familiarity, perceived hazard-risk, and personality. These factors will be discussed in this section.

Before discussing the above-mentioned factors, however, it is important to note at this point that beliefs and attitudes can affect processing at earlier stages of processing. For example, individuals who do not believe something is unsafe may not look for a warning, and even if they notice a warning they may not examine it further. This circumstance also reveals that the flow of information through the model's stages is not linear. Indeed it highly likely that all stages of processing feed back onto each other (in a loop-type fashion). The idea that a later stages affects earlier stages was first previewed with habituation at the attention stage. There it was seen that prior exposure produces knowledge of the warning in memory (after being exposed some number of times before) and this knowledge influences whether it will be

noticed subsequently.

In a similar vein to the above habituation example, people who have used the same product or performed the same task many times before will tend to perceive less risk than there actually might be. This familiarity effect has been noted in numerous research studies (e.g., Godfrey, Allender, Laughery, and Smith, 1983; Wogalter et al., 1991, in press) showing that people more familiar with a product/equipment or task are less likely to read a warning. Conversely, people less familiar are much more likely to look for, read, and comply with a warning.

However, it should not be assumed that familiarity invariably results in unsafe behavior. Indeed, some kinds of familiarity will lead to safer behavior, probably because people will know more about the situation and the hazards as well as how to avoid those hazards from information they have gained at earlier times (i.e., they have greater expertise). At the same time, such beliefs are likely to make it difficult to get people to read warnings for a new product which can sometimes be more hazardous than an older version of the product (e.g., see Godfrey and Laughery, 1984 for an examination of one product where this has occurred in women's use of newer more highly absorbent tampons causing toxic shock syndrome). In such cases, stalwart intervention steps such as making the product appear dramatically different from the old product and/or interactive warnings might help to break into people's set beliefs and attitudes.

Another important factor associated to people's beliefs and attitudes is hazard-risk perception. Persons who do not perceive a product/equipment, environment or task to be hazardous will be less likely to notice or read a warning, but even if they do, they still may not comply with its directives if they are not convinced that there is much hazard involved. Note that hazard-risk perception is closely related to familiarity. As people become more familiar with something they generally perceive it to be less hazardous. However, research (e.g., Wogalter et al., 1991, 1993b) suggests, that the hazard-risk perception to be more closely tied to warning-related behaviors than familiarity perceptions.

Even more intimately tied to hazard-risk perception is people's beliefs in how severely they might be injured. In fact, research (e.g., Wogalter et al. 1991; Wogalter, Brems, Martin, 1993b) suggests that people's notions of how hazardous a product is almost entirely based on how seriously they think they will be hurt in an injury. At the same time, people apparently do not readily consider the likelihood or probability of those injuries in making hazard-risk judgments (Wogalter and Barlow, 1990; Young, Brelsford, and Wogalter, 1990; Young, Wogalter, and Brelsford, 1992). More will be said about injury severity in the next stage processing concerned with motivation.

Other attitudes and beliefs research have focused on various kinds of individual differences (including gender, age and others). Only one individual difference, a personality factor, will be considered here. Risk taking has been postulated to affect warning-related behavior (Purswell, Schlegal, and Kejriwal, 1986). According to preliminary research, people vary in the extent to which they take risks or participate in risky behavior. From this there has been an attempt to connect risk taking with a general propensity to ignore warnings. It is not clear whether risk takers ignore all warnings or just some. Are there individuals who are otherwise safety minded but who take risks under certain circumstances such as participating in competitive sports (as is described in the next section)? It is probably true that some individuals purposely disobey certain warnings for certain reasons under certain circumstances, but it is not clear to what extent these behaviors in particular and risk taking in general predict compliance failures in other situations. The influence of personality on warning-related behavior deserves further investigation to enable a more unequivocal conclusion regarding these relationships.

Lastly, if a warning message about a particular hazard does not conform to, or is discrepant

with, an individual's existing beliefs and attitudes, then there is increased likelihood that the warning will be ignored. The basis of the discrepant beliefs may be due to one or several of the factors already discussed (e.g., familiarity, hazard-risk perception). In order for the warning to fulfil its main purpose of increasing safe behavior, it is necessary that it be sufficiently persuasive to change peoples beliefs and attitudes. Changing beliefs and attitudes is in practice very difficult to do, but the importance of accomplishing this goal is highlighted in cases where individuals may not look for or read a warning in the first place because of inappropriate beliefs and attitudes. Thus, it becomes critical for warnings to have the attention-getting and comprehension characteristics discussed earlier so that the warning has some chance of providing a persuasive argument to convince the individual to comply. A good deal of research in social psychology literature has dealt with persuasion (Chaiken and Eagley, 1976), but additional work is necessary, specifically on the factors related to warnings (McGuire, 1980; Wogalter, Allison, and McKenna, 1989). As will be seen in the next stage, persuasion is also closely linked to motivation.

3.4 Motivation

If a warning is noticed, understood, and successfully fits with the individual's beliefs and attitudes, then in order for the warning to be successful in producing safe behavior it must then motivate people to comply with its directives. One of the critical determinants of compliance motivation is the concept of 'cost' which can be distinguished in two ways: cost of compliance and cost of noncompliance.

People are usually motivated to comply with warnings because of the potential negative consequences associated with noncompliance including physical injury to themselves and others, property damage, or monetary loss. These consequences are costs that should be considered in compliance decisions. In industrial or public settings (or other controlled environments), cost of noncompliance can also include fines or penalties levied by supervisors or government agencies for unsafe behaviors. While it seems reasonable that people would want to avoid injury and loss, sometimes people do not comply with warnings designed to help them avoid such losses.

As with the cost of noncompliance, the cost associated with compliance can also be a strong motivator. Compliance to warnings, in and of itself, requires that people take some action in response to the warning message. This action can involve the expense of time, effort and/or money. If people perceive that the cost of complying to be greater than the expected benefits of noncompliance, the likelihood that they will obey the warning will be reduced. The studies cited in the following paragraphs illustrate how motivation to comply or not to comply with warnings can be affected by cost.

Several studies have examined how cost of compliance influences warning effectiveness. In one field experiment (Wogalter et al., 1987), people's behavior was observed in response to a warning posted on a broken door. People were required either to use an adjacent door (low cost), another set of doors roughly 15 meters away (medium cost), or a different set of doors roughly 60 meters away (high cost). The results showed that the warning was largely obeyed in the low cost condition (94%), but it was totally ignored when cost was high (0%). This finding was supported in another study (Wogalter et al., 1989) in which people performed a mock chemistry task. People were instructed to wear a mask and gloves while performing the procedure by the warning. The mask and gloves were either located on the table where subjects performed the task (low cost) or the items were located in an adjacent room (high cost). When the mask and gloves were nearby, 73% of the people used them as instructed. However, when the items were located in the adjacent room, less than 17% 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 warnings decrease, and that the expenditure of even a minimal amount of time or effort can dissuade a person from complying with a warning.

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 main motivators in a warning message is the consequence statement, in which the potential negative outcomes that can result from noncompliance are described. In order for this component to be effective, the consequence information should be presented using explicit language (Laughery et al., 1993b). 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 provides the user with a proper appreciation of the severity of potential injury. As described earlier in the attitudes/beliefs stage, perceptions of how severe an injury might be (more than, for example, likelihood information or personal familiarity with the equipment) to be a major factor driving people's precautionary actions (Wogalter and Barlow, 1990; Wogalter et al., 1991; Young et al., 1990, 1992). Accidents are relatively low probability events, and combined with the fact that people have difficulty discriminating or comprehending very low probabilities, it makes some sense that people do not pay much attention to likelihoods of injury. Warnings that describe the severity of the consequences explicitly have the power to motivate people to comply with the accompanying warning instructions because the hazard-related consequences are usually outcomes that people want to avoid.

In the domain of consumer products, manufacturers have virtually no direct control over user behavior after the sale. However, in the area of industrial safety, additional cost-type factors may be involved. 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 yet another cost, one of compliance, may also be present: the belief that obeying warnings and doing tasks in safe ways reduce worker productivity. If it is believed that supervisors want safety but only when it does not interfere with productivity, then this can potentially reduce the effectiveness of posted warnings. A study by Laner and Sell (1960) illustrates the importance of supervisors in affecting warning compliance. They 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 workers' slinging behavior especially when they perceived the actions to be relevant and necessary. However, the posters did not have their effect in the absence of supervisor instructions; the posters were given along with other hazard communications which reinforced the belief that management considered the safety behavior to be important.

Another study more thoroughly examined the influence of supervisor monitoring and feedback in two different industrial settings (Komaki, Barwick and Scott, 1978; Komaki, Heinzmann, and Lawson, 1980). 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 they are about as effective. 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.

Moreover, it has been suggested that warnings that promote too much fear arousal will be less effective than warnings that promote moderate fear arousal. Sometimes this outcome is called the 'boomerang' effect because it suggests that a strong warning (e.g., one that conveys disastrous consequences) will turn people off, such that they will ignore the warning. However, these notions conflict with certain other principles that say that warnings should give a fair and explicit assessment of the consequences. If the consequences are permanent crippling paralysis, severe burns from a caustic substance, or death, should this not be expressed in the warning even though the information may provoke relatively high arousal? Which recommendations to follow is not clear at this point, and further investigation is

necessary to disentangle these two conflicting proposals. Moreover, it is not clear whether explicitness, injury severity, and arousal are separable dimensions with respect to warnings. For example, some research (Laughery et al. 1993b) suggests that explicitness and severity are closely linked.

Another motivator of warning compliance is social influence. Research (Wogalter et al. 1989) shows that if people see other people comply with the warning, they will be more likely to comply themselves. Likewise, if they see someone else not comply, they are less likely to comply. Social influence like several other motivational variables is an external factor with respect to warnings (as opposed to an internal factor such as its design) but acts to affect behavioral compliance levels. Social influence is also one of several persuasion heuristics ('rules of thumb') that have been noted in the social psychology literature. However, it is noteworthy to mention that very few of the persuasion heuristics have been investigated with respect to warnings and this domain could serve as a fruitful basis for subsequent research (e.g., communication by a respected authority figure, presence of statistics).

Finally, another kind of external factor may affect compliance. Under time pressure and the presence of another person closely observing and making evaluative judgments of their performance is likely to cause stress. Stress often restricts people's attention and could result in a failure to notice a warning (or not read it even if they see it) (Magurno and Wogalter, 1994). Stress, like the other external factors (e.g., social influence), illustrates the importance of considering not only the internal design factors of warnings, but also the need for a more global systems approach that considers influential environmental and personal factors.

4. Summary and implications

This paper has given a broad overview of some of the most important issues in the design and implementation of warnings. As discussed at the outset, warnings are but one method of hazard control. There are other, usually more effective methods (e.g., design out the hazard, ban the product or outlaw the situation, guard against the hazard) to protect against accidents and injuries. The implications that can be drawn from this overview are:

- warnings should be designed so that they will be noticed and examined;
- information presented in warnings should understandable by a majority of their intended population;
- the message should have persuasive elements to ensure the correct attitudes and beliefs;
- it should motivate them to comply.

The first two stages are very important and have received the most attention in the warning research literature. Both are necessary but not sufficient conditions for warning effectiveness. The last two stages, attitudes/beliefs and motivation, are as important as the other two but are much less researched.

Thus, in addition to the attention and comprehension considerations, research and design should also focus on the factors that can affect or correct attitudes/beliefs and motivation to comply with warnings. For example, cost of compliance should be minimized as much as possible. This can be accomplished in several ways. First, in the workplace, employees could 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 (Wogalter et al. 1987, 1989). For example, if hearing protectors are required, they should be made readily available in an area where they are needed. Or if an oven cleaner requires the consumer to wear plastic gloves, the gloves should be provided. Finally, the comfort associated with safety requirements must be considered (Casali and Lam, 1986). 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 reduced when possible. Well-written and explicit warnings can give people an appreciation of the hazards and consequences associated with noncompliance. Also, if possible, active

monitoring and feedback on safety performance (both positive and negative) should be given regularly.

How do you know whether the warning has the right combination desirable features or if the environment and the people in the environment possess the characteristics to support high levels of compliance? Many of the factors discussed in this paper can be designed into the warning without a great deal of decision making, but others will cause considerable difficulty because of the tradeoffs that must be made. One potential conflict is the principle of explicitness which says that the warning should give specific information regarding the hazard and consequences. This rule will, in some situations, conflict with other principles of warnings design, for example, the provision of adequately sized print. This particular conflict becomes a problem when the explicit wording is lengthy while at the same time there is limited surface area to print the information and/or be able to read the material at an adequate distance away from the sign, and so one must trade off print size versus explicitness. Another similar and related tradeoff is with the principles of brevity and explicitness. Thus, there are inevitable trade-off decisions that must made. But how does one know whether the best decision has been made, or for that matter, whether the warning will be effective? The answers to these questions come from testing the warning using a representative sample of the target population. The results from the testing can help confirm (or disconfirm) whether the tradeoff is successful.

Testing can be done in several different ways, from subjective ratings to actual behavioral compliance. Testing can be directed at specific intermediate stages of the information processing model described in this report. Thus, the model can help to reveal where there may be problem in communication of the information (i.e., bottle neck). With this information adjustments can be made to eliminate the obstacle. The testing will often have to be done iteratively until an adequate warning can be determined.

An important point that is sometimes not considered or is forgotten in the warning design process is that measurement of warning effectiveness should continue after the warning is in place. Over time the warning is likely to be less effective due in part to the fact that people and the particular situations under which the warning is exposed changes over time. After the warning is in place, there may be the opportunities to collect data that can not otherwise be obtained in short-duration laboratory studies, such as looking behavior, purchasing behavior, and mortality/morbidity counts. The process of developing the warning and the testing should be documented. This will be useful as supporting evidence in liability suits that may arise in the future. With adequate testing, it is much less likely that a court case will arise, because injuries are likely to be reduced by well-designed warnings. But if a liability case should occur, it is much easier to convince a jury that the manufacturer did what it could when there is documentation to show that the warning was developed using state-of-the-art techniques.

A final set of points regarding the life span of warnings. Warnings should be made with durable materials. Some products and equipment have very long expected life spans, so it is important to make sure that the materials (e.g., pigments, glue, etc.) will last as long or longer than the anticipated useful life of the product. Also, many products that are purchased new are accompanied by instruction manuals. These manuals usually contain warnings and other information that may be too numerous or detailed to place directly on the product as sticker label. However, research suggests that product manuals are frequently not transferred to new owners when it is sold 'second-hand' (Rhoades, Frantz, and Hopp, 1991; Wogalter and Baneth, 1994). Given that people may need to do specific kinds of maintenance, repair etc. to ensure safe use of the product, it is important that they have access to this information. One way to ensure availability is to permanently attach a label to the product with the manufacturer's complete address and telephone number so that people can get a replacement manual (Wogalter and Baneth, 1994).

Lastly, by considering the warning factors described in this article, hazard communications

can be developed that can increase people's knowledge about hazards, but even more importantly, they can be used to reduce unsafe behavior and decrease accidents and injury.

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