Research-based guidelines for warning design and evaluation

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Abstract

During the past two decades, the body of empirical research on warning design and evaluation has grown. Consequently, there are now basic principles and guidelines addressing warning design (e.g., signal words, color, symbols, and text/content), placement (e.g., location within product instructions), and how to enhance the usability of designs by considering factors internal to the user (e.g., beliefs, perceptions of risk, stress). Similarly, evaluation methods have been developed that can be used to measure the effectiveness of warnings such as the degree to which warnings are communicated to recipients and the degree to which they encourage or influence behavioral compliance. An overview of the empirical literature on warning guidelines and evaluation approaches is provided. Researchers, practitioners, and manufacturers can use these guidelines in various contexts to reduce the likelihood that injury and product damage from exposure to a hazard will occur. © 2002 Published by Elsevier Science Ltd.

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1. Introduction

The design and evaluation of warnings has received considerable attention by human factors/ergonomics researchers over the past two decades. Research articles have been published examining various aspects of warning design and how they affect subjective evaluations, memory, comprehension, and behavioral compliance. The purpose of this article is to provide a review of the guidelines for warning design and evaluation based on empirical research. First, some of the design, environmental, and personal factors that influence warning effectiveness will be presented along with basic guidelines for designing effective warnings. Next, the factors that influence risk perception will be briefly discussed. Finally, some of the factors that need to be considered when evaluating warnings will be addressed.

When applied to warnings, design should be viewed as an activity that is initiated by requirements gathered from users. Several "user groups" must be considered when designing warnings. These groups are: (1) end-users, who are the focus of loss prevention or loss control efforts (i.e., employees in an occupational setting and consumers); (2) organizations, who will deploy the warnings and provide the context of use; and (3) product

manufacturers, who develop the products to which warning labels will be applied and who receive component materials from other entities. Therefore, a systems approach to warnings design, or one that considers the entire context, is essential. Each user group introduces design requirements and constraints that must be considered when developing effective risk communications.

How do we know that a particular warning design is effective? Warning effectiveness involves a complex set of issues. A primary approach is to evaluate or test the design. Evaluation is the activity used to determine the degree to which the warning accomplishes its intended effects (e.g., communication of risks, behavioral compliance). Very little research has been conducted comparing different methods of evaluation, despite the fact that studies often vary in the kinds of effectiveness measures employed (subjective judgments, recall or risks). Instead, research has mainly focused on the effects of design changes. For instance, some research focuses on non-text related design aspects of warnings, such as color of the design or pictorials, whereas other research seeks to assist in the design of meaningful warnings, such as the choice of signal words or the phrasing to convey consequences.

Laughery and Wogalter (1997) describe a systems-oriented model or framework of risk communication that highlights the relationships between manufacturers,

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employers, and end users, giving special emphasis to the importance of communication feedback loops. A schematic representation of the model is shown in Fig. 1. Laughery and Wogalter (1997) view warnings as a subsystem functioning within a larger communication system that includes the manufacturer, distributor, employer, and end-user as additional subsystems. These subsystems introduce varying requirements and constraints that should be applied to produce an overall warning design that fits the needs of users within a context of use, which may involve, for example, an anticipated environment or use of equipment.

In addition to the Laughery and Wogalter (1997) model, the literature on warning design and evaluation contains a number of theoretical models that have been proposed to explain how individuals perceive risk and how these perceptions influence warning effectiveness. Some models have originated from the risk analysis literature, including theoretical models based upon expectancy value theory and risk-return models (DeJoy, 1999; Weber and Hsee, 1998, 1999). These models have also been used to explain cultural differences in risk perception. Other models are based in social psychology, and have been applied in a number of ways to design risk communications to increase behavioral compliance (Ajzen and Fishbein, 1980; Bright et al., 1993; Stevens, 2000).

In order to make decisions with respect to warnings (e.g., the level of risk involved, whether to comply), there is at least some involvement of perceptual and cognitive processes. In recent years, researchers have begun to give more attention to human information processing models. The utility of these models lies in the capability of integration with social theories, producing social-cognitive models that are more useful in capturing the communication and information processing components that are specific to the risk communication process. Three such models, referred to as human information processing models, were proposed by Wogalter and Laughery (1997), Trumbo (1999), and

Wogalter et al. (1999a, b). Wogalter et al. (1999a, b) expanded the human information processing model by introducing the Communication-Human Information Processing Model (C-HIP). A schematic representation of the C-HIP model is shown in Fig. 2. This model takes into account communication components such as the source of the information, the channel used to deliver the communication, and receiver characteristics. With this revision, the new model more effectively accounts for social-cognitive components such as attitudes and beliefs about the information source (e.g., source credibility). The new model also accounts for cognitive-affective processes such as attitudes and motivation that are influenced by past experience as well as characteristics of the source and the channel.

Future models describing warning processing will likely integrate aspects related to other outside sources
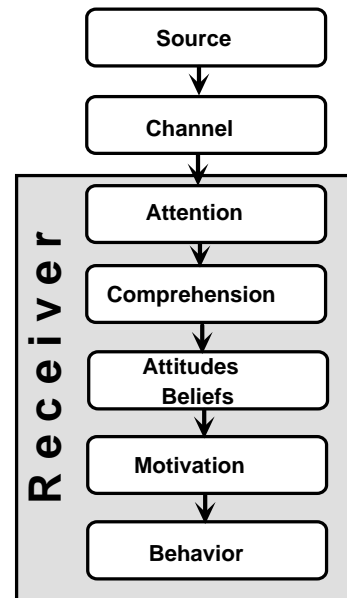
Fig. 2. Communication-human information processing (C-HIP) model. (Wogalter et al., 1999b).
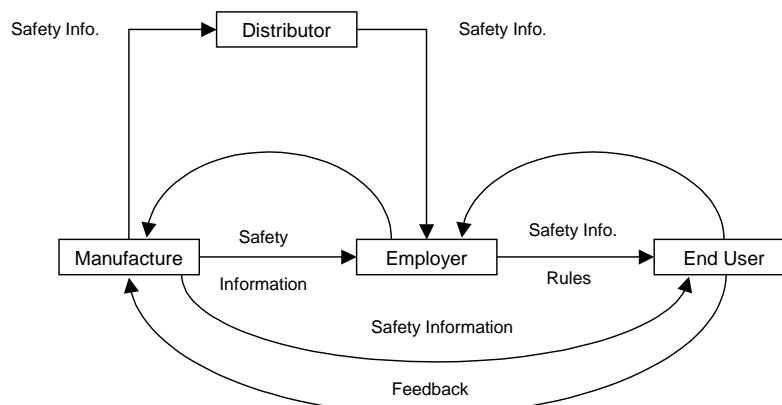
Fig. 1. Complex communication model demonstrating the various user groups and their interdependencies (Laughery and Wogalter, 1997).

and environmental context to gain a holistic or system-based view. This approach would have to be combined with model validation and revision based on evaluation within the context of use.

2. Guidelines for warning design

2.1. Salience

Getting noticed and attended to are the first requirements of an effective warning. Noticeability, which is sometimes referred to as conspicuity, is often used to describe the extent to which the design of a warning will gain or attract attention against a field of competing visual stimuli. Therefore, to have high noticeability, it is essential that a warning be as salient (e.g., stand out, be prominent, or conspicuous) as possible to capture the attention of individuals who might be focused on some other task. Research has shown that salient or conspicuous warnings increase the likelihood of reading (Strawbridge, 1986), comprehension (Young and Wogalter, 1990), recall (Barlow and Wogalter, 1991; Glover and Wogalter, 1997; Griffith and Leonard, 1995), and compliance (Hopkins et al., 1997). The salience of a visual warning can be enhanced using (1) large, bold print, (2) high contrast, (3) color, (4) borders, (5) pictorial symbols, and (6) special effects like flashing lights.

Bold type is preferred because of its greater contrast with most backgrounds, however the stroke width must not be so wide that features of individual letters are obscured (e.g., Sanders and McCormick, 1993). Adding color to a warning can increase its ability to attract attention (Gill et al., 1987) provided that the warning color is distinguishable from background and surrounding colors. Kline et al. (1993) found that colored warning labels were perceived as more readable and hazardous than achromatic labels. Warnings printed in red (compared to black) led to improved noticeability (Braun et al., 1994; Young, 1991). Wogalter and Rashid (1998) found that warning signs with thick, colorful borders were more likely to attract attention (determined by looking behavior of passers-by) compared to similar signs with thin or no borders. Warnings with text and pictorial symbols are more likely to attract attention (Kalsher et al., 1996; Laughery and Young, 1991; Sojourner and Wogalter, 1998).

Salience can also be enhanced through interaction with the warning. Raised borders providing tactual cues have also been shown to increase perceived warning noticeability (Kalsher et al., 1997). Locating warnings such that physical manipulation of the warning is required for product use has been shown to result in greater noticeability, recall and compliance (Dingus et al., 1993; Duffy et al., 1993). However, knowledge of

task behavior is crucial to design interactive warnings, so behavioral and cognitive task analyses should be conducted (Frantz and Rhoades, 1993). A behavioral task analysis involves breaking down the task into component task elements, activities, and sequences. A cognitive task analysis involves breaking down the mental processes into components such as decision points and information that must be recalled.

2.2. Wording

An effective warning consists of four message components (e.g., Wogalter et al., 1987a, b), each of which serves a different purpose: (1) signal word to attract attention, (2) identification of the hazard, (3) explanation of consequences if exposed to hazard, (4) directives for avoiding the hazard. First, a warning should contain a signal word to attract attention to the warning and indicate the level of hazard present. A number of studies have examined the understandability and hazard perceptions associated with signal words. The four most common signal words (and those recommended for use by the American National Standards Institute (ANSI, 1998) Z535 Standards on Safety Signs and Colors) are DANGER, WARNING, CAUTION, and NOTICE. With few exceptions (e.g., Leonard et al., 1986), signal word research has consistently shown that DANGER connotes the greatest degree of hazard and NOTICE the least. The perceived distinction between the intermediate terms WARNING and CAUTION is less clear (Braun and Silver, 1995a; Chapanis, 1994; Drake et al., 1996; Leonard et al., 1988; Silver and Wogalter, 1989; Silver et al., 1993; Wogalter et al., 1992, 1994, 1995). Research indicates that the presence of a signal word in warnings increases its effectiveness (Wogalter et al., 1985a, b; Young et al., 1995) and the level of perceived hazard (Wogalter et al., 1992, 1994).

A second warning component should describe the nature of the hazard present in the situation. The hazard description should be specific and complete. For example, it might involve an explanation or description of the mechanisms involved so that people will understand the nature of the hazard. At the same time, the hazard description should not be so lengthy that few people will take the time and effort to read it. Therefore, there is a need to balance completeness and brevity.

Third, a warning should describe the possible consequences of non-compliance. A specific description of the mechanism of injury provides more information and informs individuals why it is important that they comply. The list of consequences should be explicit and should map to the hazard descriptions. For example, a chemical hazards warning could explicitly state that "Severe lung injury can result" as opposed to stating the consequence non-explicitly (e.g., "You could be in-

jured"). More explicit warnings have been associated with greater levels of perceived dangerousness, hazard understanding, perceived injury severity, intent to act cautiously, manufacturer's concern, and protective equipment use (Braun et al., 1995; Dingus et al, 1993; Laughery and Brelsford, 1991; Laughery and Stanush, 1989; Laughery et al., 1993; Young and Wogalter, 1998).

Finally, the warning should offer directives or instructions on how to avoid the hazard. It, too, should be explicit. For example, a warning should state the type of protective equipment to be worn to avoid injury to lungs, rather than provide a vague reference to personal protective equipment. Hazard avoidance instructions should describe specific actions that need to be taken (or avoided) by the warning recipient for safe behavior.

If one part of a warning conveys information relevant to another part (e.g., if the consequences of the hazard are obvious by the statement that identifies the hazard or is communicated by a pictorial symbol), then the consequence information need not be communicated as a separate statement. This rule of thumb is also true of hazard descriptions and instructions, that is, there is no need to give a separate statement for a component message if the other components of the warning make the information obvious.

2.3. Layout and placement

The layout of a printed warning also influences effectiveness. Layout is used to describe the internal characteristics of a warning label. Presenting warning text as bullets in outline form is preferred to continuous flowing text. Warnings in outline form are judged as more appealing, easier to process, and more effective than other layouts (Hartley, 1994; Wogalter and Shaver, 2001). Compared to paragraph layouts, outline formats maintain attention longer and produce greater compliance (Desaulniers, 1987). Figs. 3 and 4 show a paragraph and list format from a Wogalter and Shaver (2001) study of warning design to communicate risks that may result in Toxic Shock Syndrome. In this study, a list format resulted in less search time, compared to a paragraph format. Alternative label designs have also been investigated. Researchers have found that tags and fold-outs were preferred over traditional labels for pharmaceutical containers (Kalsher et al. 1994; Wogalter and Young, 1994).

Placement or location relates to where the warning will be embedded within a context of use. The proper placement of a warning depends on the nature of the task being performed as well as the task environment. A well-designed warning will be of little use if the user does not encounter it in the task environment. For example, the placement of a warning within a task setting will increase or decrease the likelihood that it is noticed and

Primary symptoms of TSS are sudden high fever (usually 102° or more), and vomiting, diarrhea, fainting, or near fainting when standing up, dizziness or rash that looks like a sunburn. There may also be other symptoms of TSS such as aching of muscles and joints, redness of the eyes, sore throat and weakness. If you have sudden high fever and one or more of the other symptoms, remove your diaphragm and consult your physician immediately. Women with a known or suspected history of TSS should not use the diaphragm.

Fig. 3. TSS symptoms in paragraph format (Wogalter and Shaver, 2001).

Primary symptoms of TSS are sudden high fever (usually 102° or more), and one or more of the following:
    vomiting
    diarrhea
    fainting, or near fainting when standing up
    dizziness
    rash that looks like a sunburn
    aching of muscles and joints
    redness of the eyes
    sore throat
    weakness
If you have sudden high fever and one or more of the other symptoms, remove your diaphragm and consult your physician immediately. Women with a known or suspected history of TSS should not use the diaphragm.

Fig. 4. TSS symptoms in list format (Wogalter and Shaver, 2001).

comprehended. Warnings are most effective when they are presented proximate (in time and space) to the hazard. Frantz et al. (2000) found that 98% of participants noticed a warning that was located on the physical object associated with the task (in their case, a file cabinet). The placement of warnings included with product instructions has been shown to influence their effectiveness, but research findings are equivocal. Some research indicates that warnings should be placed before the instructions (Wogalter et al., 1985a, 1987b), while other research indicates that warnings should be embedded within the instructions (Frantz, 1993, 1994; Frantz et al., 1993).

The amount of visual clutter in the vicinity of a warning significantly influences warning detection times (Godfrey et al., 1991; Wogalter et al., 1993). Godfrey et al. found that warnings placed on the front label of a bottle printed horizontally were found more quickly than any other position. One possible way of reducing visual clutter on product labels is to increase the surface area of the label by using extended tags (which alters the layout of the warning). Wogalter and colleagues (1994, 1996) found that the use of such supplemental labels increased the salience of the warning relative to a traditional container label.

2.4. Pictorial symbols

As noted earlier, including pictorial symbols in warnings increases their salience and likelihood of being noticed. The presence of pictorials has also been shown to enhance memory of a warning (Young and Wogalter, 1988). A warning must first be legible (early stage of information processing) before it can be comprehended (later stage of information processing). Legibility refers to the degree of initial clarity of the warning. Thus, legibility is based on size of the pictorial and is affected by the distance from which it will be viewed. Environmental conditions such as sunlight, humidity, temperature, or the presence of certain chemical substances, can erode the legibility of a warning over time. The legibility issue is of particular concern for older recipients whose eyesight may be deteriorating and in environments where vision is obscured (by smoke or fog). Pictorials are most effective when they communicate simple, concrete concepts, and are less effective at representing abstract concepts (Murray et al., 1998). When designing pictorials, one needs to include enough detail to convey meaning without providing so much detail that legibility and comprehension are reduced. Pictorials and text should always be tested before they are used.

Another important function of pictorials is to facilitate warning comprehension (Dewar, 1999). Comprehension is the degree to which the recipient understands the warning, based upon the intended meaning the warning is designed to convey. Both the ISO 3641-1 (Organization of International Standards, 1988) Standard and the ANSI Z535 Standard have established minimum acceptable levels of comprehension by the general population (67% and 85%, respectively). The comprehensibility of a warning is especially important for audiences who cannot read (e.g., children and illiterates) or who might not understand the language used in the wording of the warning. The presence of pictorials has been found to enhance memory of a warning (Young and Wogalter, 1988).

Examples of a warning format recommended in design guidelines in the United States are shown in Fig. 5.

2.5. Auditory warnings

Technology has enabled the production and use of inexpensive digital voice chips (e.g., those found in answering machines) that can be coupled with sensor technologies such as motion detectors to present auditory warnings. Auditory warnings offer advantages over visual warnings in certain situations and environments because of their generally omnidirectional nature and ability to attract attention. Auditory warnings may be used when the visual environment is highly cluttered and when the message is relatively short and simple. They can be used to call attention to the need to examine a visual warning for more information. Auditory warnings may take several forms: simple or complex tones, auditory icons, and speech (verbal) warnings. Non-verbal auditory warnings can be made more urgent by changing the physical characteristics (pitch, frequency, pulse rate) of the sound.

Using a parking aid system that alerts drivers who are traveling in reverse, Zobel (1998) found that a warning tone frequency of 750–1000 Hz with a pulse rate greater than 6 Hz is perceived to be more urgent than a similar tone with a pulse rate <6 Hz. In a simulated driving task using both front-to-rear and side collision scenarios, a tire skid sound and a long horn honk resulted in improved driver performance over multi-tone or frequency-modulated auditory warnings (Belz et al., 1998). Haas and Casali (1995) found that more urgent auditory warning signals produced faster response times. While the meaning of non-verbal auditory warnings must be learned, voice warnings can make use of existing
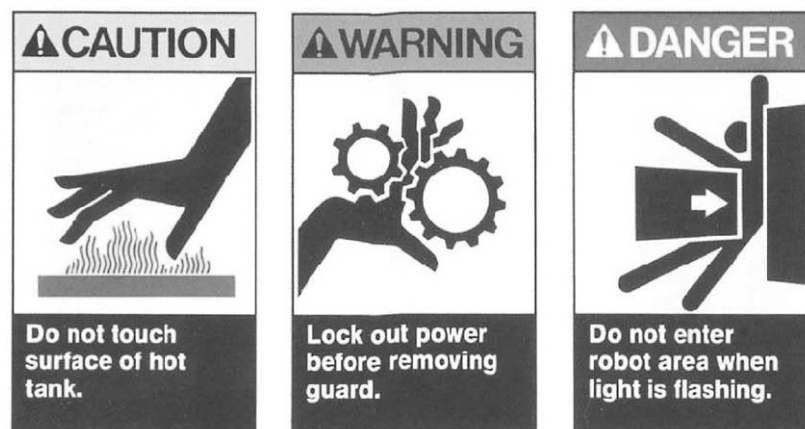

Fig. 5. Representative warning designs used in the United States (Wogalter et al., 1999b).

knowledge. The presence of a voice warning produced a strong and reliable increase in compliance compared to conditions without a voice warning (Wogalter et al., 1991). In addition, the characteristics of the warning message (i.e., frequency, repetition, variability, gender of voice, and rate) can affect perceived urgency (Barzegar and Wogalter, 1998, 2000; Edworthy and Hellier, 2000; Hollander and Wogalter, 2000). One caveat associated with the use of auditory warnings is that their attention grabbing ability can lead to annoyance, particularly if there is a high incidence of false alarms. In addition, auditory warnings may not be appropriate if their addition to existing noise causes noise annoyance or interferes with critical communications.

2.6. Personal factors

A number of personal factors (i.e., those not related to the design of the warning or the environment in which it is placed) also influence warning effectiveness. These include demographic variables such as age, gender, cultural background, product or task familiarity and training, and individual differences. Conzola and Klein (1998) found that individuals with a higher need for cognition, based on scores from the Need for Cognition (NFC) Scale (Cacioppo and Petty, 1982), judged warnings to be more important compared to individuals low in the need for cognition. Other studies by Haugtvedt and Petty (1992) have shown that individuals high in NFC are more resistant to attitude change. Attention has also been focused on high hazard perceivers, which is believed to be a trait reflecting a tendency to perceive hazards in the environment (Hellesoy et al., 1998) and on social responsibility, which is thought to lead to a higher likelihood of obeying rules and warnings (Gramann et al., 1995). In general, warnings are more likely to be noticed and read if they are particularly relevant to a specific group or individual. For example, alcoholic beverage warning labels were more likely to be noticed by heavy drinkers, young men, and women of childbearing age (Kaskutas and Greenfield, 1991). Wogalter et al. (1994) found that warnings containing a direct reference to the individual (using the participant's name) led to higher compliance compared to a warning containing no reference to the individual.

2.6.1. Demographic variables

Age: As people age certain physical and cognitive changes occur that could influence the ability of older individuals to perceive and process warning information. Print must be large enough to be viewed by older users. To accommodate the enlarged print, alternatives such as fold-outs (Morrell et al., 1990; Vigilante and Wogalter, 1999) and clearer layouts using spacing or bullets (Hartley, 1994) can be used. The legibility of printed warnings becomes especially important for older individuals whose visual acuity has decreased. Wogalter and Dietrich (1995) found that for pharmaceutical container caps, elders from a retirement community preferred cap labeling and a distinctive florescent green background color. In addition, making use of extended surface areas on medication containers to print important information in a more noticeable and legible format benefits the elder's knowledge about the proper use and hazards associated with a medication (Wogalter et al., 1996). With age, short-term memory capacity decreases (Light and LaVoie, 1993; Salthouse, 1990). Therefore, warnings intended for older adults should be kept as brief and direct as possible. Bruyas (1997) found that older persons encounter some difficulties in establishing links between symbols and tend to focus on elements other than those used by younger subjects. Warning designers need to consider these factors when the recipients of a warning are likely to include older individuals.

Culture/ethnicity: As cultures around the world become increasingly diverse, it becomes increasingly important to effectively communicate safety information to peoples of different languages and cultures. Warnings (especially those found in public environments like airports and train stations) should use language independent pictorials and symbols whenever possible. Further studies must be pursued to develop and validate pictorials, icons, and symbols that are less culture-dependent. Designers must be aware of intercultural differences (due to the broadening of international trade) and intracultural differences (subcultures within a dominant culture) and should display caution when designing warnings for contexts consisting of a variety of cultures (Smith-Jackson and Wogalter, 2000).

Research has shown that English signal words are not well understood by Spanish speaking people (Wogalter et al., 1997) and that symbols developed in the Netherlands were less well comprehended in other European countries (Trommelen and Akerboom, 1997). In addition, some differences in the hazard connotations of colors and symbols have been found between Spanish speaking people and English speaking people (Smith-Jackson and Wogalter, 2000). Because warning components that are effective in one culture may not be effective in others, it is important to do cross-cultural testing of warnings whenever appropriate and possible.

Gender: Most research has failed to find or report gender differences on warning related measures. The few studies that do report significant gender differences indicate that females are more likely to read, comply with, and find importance in warning information (Godfrey et al., 1983; LaRue and Cohen, 1987; Vredenburgh and Cohen, 1993). In addition, researchers have found differences in risk perception between genders, with most studies supporting higher risk

perception among females compared to males (Fischer et al., 1991; Flynn et al., 1994), but specific application to the design or re-design of warning components is not yet understood. In general, gender factors are not relevant to warnings unless the warning is more relevant to one gender versus the other as in warnings for gender-specific products like feminine hygiene products (Young et al., 1989).

2.6.2. Familiarity and training

Familiarity reflects an individual's beliefs, knowledge, and experience in a specific domain. In general, familiarity varies inversely with warning detection (Goldhaber and deTurck, 1988a, b), perceived hazard (Godfrey et al., 1983), perceived risk (Karnes et al., 1986), and compliance likelihood (Goldhaber and deTurck, 1988a, b). People are more likely to notice a warning the first time that they use the product than if they switch to a similar product (Godfrey and Laughery, 1984). Safety messages in familiar situations on familiar products are less likely to be given attention (Nikmorad, 1985; Otsubo, 1988; Purswell et al., 1986). Prior injury experiences may mediate these effects. Martin and Wogalter (1989) found that people who had been injured or had knowledge of others who had been injured while using a consumer product reported higher precautionary intent than those without such experience.

Familiarity is also an important factor in warning habituation. The more often a warning is encountered, the less likely the person will notice it on subsequent encounters. While a warning may not be given primary conscious attention in a familiar context, the warning can still cue long-term memory information, and thus, facilitate transfer to working memory resulting in conscious awareness of the potential hazards. One method that has been used to dampen the negative effects of habituation is to change the content or appearance of a warning to reduce redundancy effects. If multiple warnings are presented on a rotating basis, individuals will be exposed to a specific warning stimulus less frequently and habituation is less likely to occur. Wogalter and Brelsford (1994) rotated warnings on alcohol beverage labels resulting in a significant increase in knowledge of hazards, compared to hazard knowledge from presentation of a single label design.

Like many other behaviors, behavioral responses to warnings can be trained using strategies such as modeling, laws and regulations, or employee education efforts (Geller, 1998). For example, power plant operators are trained how to respond to various warnings that indicate that a plant system is operating out of the desired range. Training is especially important when an immediate or complex response to a warning stimulus is required. In such situations it might be difficult, if not impossible, for an individual to comprehend what actions need to be taken based solely on the limited information presented in a warning. The power plant operator should be trained how to respond to the various warning alarms he/she may encounter without having to look for instructions in a procedure manual.

It is not feasible to design a warning for every individual difference or personal characteristic, however, when testing a warning it is feasible to include a representative sample of the target population to which the warning will apply. Guidelines for warning design and measures of warning effectiveness should be based on studies that include a variety of appropriate population samples (Cox III et al., 1997; Wogalter et al., 1987b).

3. Guidelines for evaluation of warnings

3.1. Evaluation processes

Very few warnings in the "real world" have actually been evaluated or tested for efficacy. To determine whether a warning is "working", one must use a systematic evaluation process. Evaluation processes fall into two main categories, formative and summative evaluation.

3.1.1. Formative evaluation

Formative evaluation occurs while the warning is being designed (similar to usability research in human-computer interaction). Using this approach, design and evaluation occur in parallel. For instance, design mock-ups can be tested on participants representing the target group, and then altered on the basis of feedback or results of criterion measures. This approach supports iterative design of warnings, such that the warning can be changed repeatedly throughout the process, until a final iteration is agreed upon. The advantage of formative evaluation is the ease of identifying problems early in the design cycle. When to cease formative evaluation is likely based upon a number of considerations, including cost, criticality of the warning system, and information gain from each evaluation.

3.1.2. Summative evaluation

Another approach is summative evaluation. Summative evaluation involves testing the final warning label (s), after all design activities have been completed. Summative evaluation can be the sole approach to evaluation, or it can be combined with formative evaluation. In summative evaluation, the final product must be "released" into the context of use, and then criterion measures can be gathered from participants over a period of time deemed appropriate for that particular warning. Since summative evaluation requires

a completed design and testing within the real-world context, it may, at times, be more costly than formative evaluation. In addition, problems discovered from summative evaluation may lead to costly changes that may have been easier to fix during the early design and development stages.

3.2. Measurement considerations

Regardless of process, any decision to evaluate a warning must include careful selection of criteria to be used to draw inferences regarding warning effectiveness. These criteria should match the intentions of the warning designers. Ideally, all warnings should be developed and tested by measuring the criterion of behavioral compliance in real world environments. Unfortunately, it is not always possible to measure compliance. The costs and risks associated with compliance studies preclude their use in many, if not most, situations. Some researchers have used behavioral intent as a substitute measure of behavioral compliance, basing their assumptions on the empirical literature from such researchers as Bright et al. (1993), Doll and Orth (1993), Ellis and Arieli (1999), and Vallerand et al. (1992). Studies have measured behavioral intent through direct interrogation of participants about intent to act or behave or by having participants rate their likelihood of behaving or acting in a specific manner.

If measuring compliance is not possible, the best strategy for evaluating warning effectiveness is to use a number of different measures that may converge on the same or similar results (triangulation), but this can be costly to implement. It is also important to consider the context of evaluation. For example, results may differ when testing pictorials in the actual context of use versus presenting the pictorial without environmental cues (Wolff and Wogalter, 1998). The goal of much warning research is to identify and improve those features of warnings that facilitate processing of warning information so that the likelihood of compliance is increased.

3.2.1. Subjective measures

In most warning studies multiple subjective measures of warning effectiveness are employed (Young and Lovvoll, 1999). Participants typically rate warnings along several dimensions using Likert-type scales. Measures of noticeability, reaction time, comprehension, recall and knowledge have been used to assess warning effectiveness. In addition, subjective ratings of hazardousness, perceived urgency, and risk, as well as likelihood of injury, likelihood of compliance, and importance are often used. Strong positive correlations have been found among ratings of product hazardousness, likelihood of injury, severity of injury, likelihood of compliance, and carefulness (Drake et al., 1998) indicating that they are measuring a single construct,

which might be referred to as injury potential. Some of the design features that have been found to increase hazard ratings include larger print (Adams and Edworthy, 1995; Braun and Silver, 1995b), the use of color (especially red), and various border shapes such as triangles, diamonds and octagons (Cochran et al., 1981; Collins, 1983; Riley et al., 1982). In addition, the source attributed to warning information has been shown to influence its hazard ratings and believability (Resnick, 1998; Wogalter et al., 1999a, b).

Other methods to gain subjective reports can include paired comparisons of design alternatives followed by ratings of various dimensions such as likelihood of compliance or criteria related to usability, such as comprehensibility, noticeability, coherence, or legibility (Young and Lovvoll, 1999). This will help designers to determine the most effective warning from a collection of design alternatives. Participants can also rank design alternatives on the basis of dimensions mentioned above, or dimensions that are self-selected as important (open-ranking or sorting method). Allowing an open ranking or sorting activity helps the designer determine which criteria are most important to the user. This method must be followed by an interview to clarify the dimensions that were important to each participant.

3.2.2. Objective measures

Objective measures involve assessing the user's performance to determine warning effectiveness. Objective measures traditionally used in warnings evaluations are observation and measurement of recall. Observation in a pseudo-realistic or contrived situation can be used to identify compliance behaviors and to understand how a warning is processed by the user. For example, a checklist can be developed so that an observer can check off behaviors that are consistent with compliance within a task scenario. Participants can also be asked to think out loud when completing the task and using the warning label. This approach, known as a verbal protocol (Ericsson and Simon, 1980) provides additional data on the participant's awareness and comprehension of a warning. Verbal protocols can be conducting concurrently with the task, or retrospectively (after the task has been completed).

Alternatively, a large body of warning research is based on measures of the intermediate processes concerned with the stages of the information-processing model (e.g., attention), which occur prior to behavioral compliance. A measure of the user's incidental recall accuracy (recall after one exposure followed by a "pop" quiz) provides a measure of the extent to which the warning communicated the risk information and mimics real-world exposure scenarios. A warning's ability to facilitate recall is important, because warning information might not always be available when hazards are encountered. Wogalter et al. (1991) found that

compliance behavior was significantly related to memory of a warning. Factors that aid in the recall of safety information include repetition (Wogalter and Brelsford, 1994), warning relevance (Gardner-Bonneau et al., 1989), pictorials (Young, 1988; Young and Wogalter, 1990), and the presence of injury statistics (Conzola and Wogalter, 1998).

4. Final note

This article reviewed pertinent literature on the design and evaluation of warnings. Developers are reminded to use a holistic development framework (system approach) and to consider the context in which the warning will be embedded, its design and placement, and the demographics of the target user group. Use of formative and summative evaluation within a system framework will support a cost-effective, user-centered approach to the design of warnings.

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