TECHNOLOGY-BASED WARNINGS: IMPROVING SAFETY THROUGH INCREASED COGNITIVE SUPPORT TO USERS

Christopher B. Mayhorn and Michael S. Wogalter

Psychology Department, North Carolina State University, Raleigh NC, 27695-1708 USA

WogalterM@aol.com

New and emerging technologies promise to revolutionize risk communication. The benefits of technology are discussed with respect to the components of a recently described warning process model. Examples are provided to illustrate how technology can potentially improve information accessibility and cognitive support. Design principles such as warning interactivity, dynamic modification, and personalization are considered as potential applications of technology that should enhance warning effectiveness in future technology-based systems.

INTRODUCTION

The main purpose of warnings is to reduce the likelihood of injury to people and damage to property. Future warning systems will likely have properties that are different and better than traditional static warnings such as labels. Recent technological developments including new wireless handheld devices may provide dynamic warnings in applications heretofore not considered. This article describes how existing and future technology can be applied to warnings and risk communication to improve information accessibility and provide cognitive support. Here, cognitive support refers to the assistive aspects of technology which enhance the mental capabilities (and avoid the limitations) of users.

To demonstrate how technology-based warning systems might contribute to user safety, the benefits of technology adoption will be discussed in the context of a basic warning process model. The framework used in this article to organize our discussion of technologically-enhanced warning systems is described by Rogers, Lamson, and Rousseau (2000). In this model, a user's interaction with a warning involves four broad components: notice, encode, comprehend, and comply. Each component of the Rogers et al. (2000) framework is described in separate sections with examples provided to illustrate how technology might be implemented to benefit warning effectiveness.

NOTICE

The first stage in the Rogers et al. (2000) model is noticing the warning. The warning must first be noticed to be effective. In this stage, the warning ought to draw attention to itself to enable the processing of information to move to subsequent stages of the model.

According to Laughery and Young (1991), warning noticeability can be enhanced through the manipulation of physical design characteristics (e.g., adding a distinctive color, adding a pictorial symbol, or using larger font, etc). Yet color and most other physical design factors of traditional printed warning labels are static. They are passive in the sense that they do not change. A simple method used to improve noticeability is to have something that catches the eye such as a flashing light adjacent to a warning. This type of active or dynamic warning provides stimulus change that draws attention.

Why is stimulus change important for warnings? In some contexts, an unchanging stimulus can produce habituation which means that the stimulus is becoming less attractive of attention. Furthermore, when an individual is repeatedly exposed over time to the same stimulus, less attention tends to be given to that stimulus at subsequent exposures. Stimulus change may thus slow the habituation process.

Consider a road sign stating "Bridge freezes before the road." This sign is often permanently erected and visible during summer months when freezing is not relevant. As a result, it is appropriate to ignore the sign when the conditions are not relevant. This becomes a problem when people do not recognize the weather conditions make the sign relevant. A potential solution is to use temperature detectors so that presentation of the icy bridge sign is limited only to cold weather.

Thus one of technology's main benefits to facilitating warning noticeability is that it enables the dynamic modification of its appearance every so often. Of course, the perceptual consequences of the stimulus change needs to be sufficiently large to benefit noticing and limit habituation. There are two types of "noticing" that will likely be incorporated in future warning systems. One is to have the system detect the hazard or at least a surrogate of the hazard. The other is to aid the user or receiver in noticing the warning. These are discussed in the next two sections.

Placing the burden of "noticing" on the system

Advanced warning systems are likely to incorporate sensors that can detect hazardous conditions. There are numerous detection systems available today that can "sense" motion, heat, and weight. In one empirical demonstration, Wogalter et al. (1993) used an infrared photoelectric detection system to initiate a warning presentation when individuals entered a designated risk area. This system "notices" and then delivers a warning. A portion of the noticing process has been allocated to the system to assist the user.

The kinds of conditions that may be detected by sensor devices are quite varied. Sensors can detect the presence of the hazard itself or correlates of the hazard such as persons (or other things) entering a restricted environment or doing some other potentially hazardous activity. One example is a carbon monoxide detector that "senses" the presence of this odorless poisonous gas. Technology is doing the detecting for us.

The sensors do not necessarily have to detect a person or thing, but could detect correlated indications of the presence of a person or thing. For example, certain kinds of sensors in an automobile could detect the presence of an infant/child seat rather than the presence of a child. Complex sensor configurations involving different types of sensors could detect more specific indications of hazards. For example, using both a weight and motion detector is likely to provide a more accurate assessment of the presence of a small child and not a child seat alone. The system could display a warning in one instance and not in the other.

Enhancing the display

Technology can enhance warning displays in a number of ways. There are numerous features that can enhance the ability of visual displays to attract attention, such as the presence of color, size and the presence of pictorial symbols (Wogalter and Leonard, 1999). The benefit of technology is that when connected to a computer with the appropriate programming, the display can be more dynamically targeted to the particular user. For example, if a user is red-green color blind or has auditory insensitivity at certain frequencies, the sensory characteristics can be modified to give a compensatory presentation in a different modality. Other examples of a technology-enhanced display are digitized voice systems. There are currently inexpensive miniaturized voice production units in consumer products such as answering machines and greeting cards. This digital recording and presentation technology could be employed to present noticeable voice warnings.

ENCODE

Once the warning is noticed, processing may continue so that warning information is translated and stored as some internal mental representation. Considerable cognitive research on learning and memory shows that numerous factors that benefit (and reduce) the encoding of information. For example, one well-studied method shows that spaced presentation (distributed across different points in time) yields better encoding (and thus subsequent performance) than massed presentation (cramming) while holding constant total presentation time (Underwood, 1961). Thus, in some cases, the learning of safety information could be facilitated by programming systems to distribute presentations across time rather than giving them all at once.

For the presentation of complex information the system could provide cognitive support by presenting the tasks in a step-by-step format. This could be accomplished, for example, by using a method similar to the "talking box" used in a study by Conzola and Wogalter (1999). When participants opened the box, a miniaturized voice system delivered a sequence of precautionary steps to be performed before installing a computer disk drive in the box. With safety instructions that require numerous complex steps, working memory could be overloaded if the sequence is provided in one continuous presentation. To provide cognitive support in this instance, the system could give carefully-timed or user-prompted instructions to reduce the likelihood of overloading the cognitive system.

COMPREHEND

Although users may notice and encode the words

or graphics of a warning display, they still may not understand the intended message. Consider the warning statement "Contains Carbon Monoxide." This statement would not be an effective warning if the receiver does not know that this gas is poisonous. Generally, it is better to have no understanding of a warning that has benign effects than have it create a misunderstanding or confusion that creates a hazard. For instance, certain medications display a picture with a pregnant woman with a slash prohibition symbol meant to indicate that pregnant women should not take this drug. If this symbol were misinterpreted as an illustration for birth control, the consequences could be disastrous.

Receiving more information

Electronic warnings can allow the presentation of more detailed information beyond the initially-displayed warning material. As with links in hypertext or on pages of the web, users can call up richer descriptions of related information. Dynamic displays can provide different information over time.

Other examples of technology-based warnings benefiting comprehension include electronic display boards erected on busy, urban highways. These massive changeable signs are currently erected for the purpose of alerting drivers of the road conditions ahead. These displays could improve comprehension of traffic conditions by making available additional information such as the approximate length of delays or alternate routes that might be taken. Also, advanced navigation systems in vehicles could receive and voice this information to drivers.

Tailoring safety information

In contrast to static signs or labels, dynamic electronic warnings offer the flexibility of changing the physical characteristics and message content of warnings. The information presented can be tailored to the hazard level of the situation or to the receiver's particular array of characteristics to benefit comprehension.

Previous work has indicated that different colors have different hazard connotations (e.g., Chapanis 1994, Wogalter et al, 1998). For example, red is generally understood (in some cultures) to connote greater hazard or urgency than other colors. Thus, in applications the color displayed in a warning could be changed to reflect the current level of danger. Voice and sound modifications can also be used to produce different levels of perceived urgency (Edworthy and Hellier 2000).

Comprehension can also be benefited by tailoring the warning message to user characteristics such as the experience level of the user. Technology could be used to warn users who are insufficiently skilled from using certain equipment. Detection of expertise level could involve some of the sensor methods already described in this article. With a diverse user population, an advanced system would adapt to the user's demonstrated or desired skill level. Expert users might benefit from the use of technical information, whereas novices will likely be confused by such content. Novice users would initially receive only the basic information, but over time, as their expertise develops, they would receive more and different information.

COMPLIANCE

An important goal of warnings is to increase safe behavior and decrease unsafe behavior by guiding users to make the appropriate decisions and actually carry them out. One way to benefit compliance is to show other people performing the compliance behavior thereby providing a model of safety. Video can allow users to see how a task can be accomplished safely. Indeed, research shows that participants are more likely to imitate warning compliance when they view a video tape showing a model carrying out the correct behavior compared to a static warning sign instructing the same behavior (Racicot and Wogalter 1995).

Increasing compliance through personalized warning information

Personalized warnings, which we have described as potentially useful at earlier stages of the warning process, can also benefit the performance of compliance behavior. Research shows that personalized warnings that incorporate the receiver's name (instead of a signal word) produce higher rates of compliance of donning protective equipment of users performing a chemical mixing task (Wogalter, Racicot, Kalsher, and Simpson 1994). Part of the reason compliance may be benefited in the above study is that including the user's name adds relevance; otherwise users may believe the warning is not necessarily directed to him or her.

Decision-making support might be provided to make specific situational recommendations based on information gleaned from sensor data. To illustrate, researchers at the

Veterans Administration hospital in Atlanta, Georgia recently developed an expert system to make recommendations concerning exercise regimens for older adults (Boyette et al., 2001). An advanced warning system with access to an expert system could monitor older adults' vital signs through a wearable sensor and actively intervene to warn to slow or stop the exercise (i.e., invoking compliance) if their heart rate rises above a criterion.

Reducing the cost of compliance

Video displays that demonstrate safety procedures may serve to benefit compliance behavior because they can reduce the amount of cognitive effort users must put forth to learn the correct procedures. Research shows that compliance is more likely when the directed behavior is relatively easy, or in other words, cost of compliance is low (Hunn and Dingus, 1992). Clear, unambiguous presentations should reduce cognitive load and decrease misunderstandings that might result in incorrect procedures being performed.

CONCLUSION

Technology-enhanced warnings should result in improved access to safety information and provide cognitive support to aid users in making higher quality risk-related decisions. Future technology-based warning systems promise to provide improved access to safety information and cognitive support for each of the components of the warning process. Here, the Rogers et al. (2000) model provided a simple structure to guide discussion of how technology can improve warning effectiveness. Specifically, the goal of improving user safety can be accomplished by capitalizing on the interactive capabilities of technology and its ability to personalize warning information through dynamic modification of content.

This article was not intended to provide a comprehensive review on all the ways technology-based warning systems could be implemented. Instead, the goal was to highlight some of the potential benefits of technology and to provide direction for future warning development and research. While much empirical work and modeling remains to be done, the promise of more advanced, technology-based warning systems is enticing.

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