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PROVIDING COGNITIVE SUPPORT WITH TECHNOLOGY-BASED WARNING SYSTEMS

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Applications of technology promises to transform conventional methods of risk communication. The benefits of technology are discussed in the context of a recently described warning process model. 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. Examples are provided to illustrate how technology could improve information accessibility and cognitive support.

INTRODUCTION

Warnings are intended to reduce 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. Technology such as wireless handheld devices can provide dynamic warnings in applications not previously considered. This plenary paper 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 may 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 will be discussed in the context of a simple information-processing model that includes attention, comprehension, persuasion and compliance. Each component or processing stage of the model will be described along with examples to illustrate how technology might be implemented to benefit warning effectiveness.

TECHNOLOGY BENEFITING STAGES OF INFORMATION PROCESSING

A warning must first be noticed to be effective. The warning should draw attention to itself to enable the processing of information to move to subsequent stages of the model. 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, passive, and do not change. One method that could be used to improve noticeability is to flash a 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." Because the sign is often permanently erected and visible during summer months when freezing is not relevant, people learn the sign is not relevant. When the critical time comes when the sign is relevant such as when ice is present, individuals may not give adequate attention to the sign. Using temperature detection devices, presentation of the icy bridge sign could be limited only to cold weather conditions.

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 issues are discussed next.

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, Kalsher, and Racicot (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. Thus, 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. Complex sensor configurations involving different types of sensors could detect specific indications of hazards. Using both a weight and motion detector is likely to provide a more accurate assessment of the presence and location of a small child in a passenger seat than one detector alone.

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., and potentially 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.

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 affect the encoding of information. For example, 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, programming systems to distribute presentations across time rather than giving them all at once could facilitate the learning of safety information.

Future warning systems could provide cognitive support by presenting tasks in a step-by-step manner. This has some similarity to the "talking box" method 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.

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 reader does not know that this gas is poisonous. Moreover, there are potential problems of a misunderstanding or confusion. For example, certain medications have included a pictorial representation of a pregnant woman with a slash prohibition symbol meant to indicate that pregnant women should not take the drug. If the symbol were misinterpreted as indicating a method of birth control, disastrous consequences could result.

Electronic warnings can allow the presentation of more detailed information beyond the initially displayed warning material. As with links in hypertext or on the web, users can call up richer descriptions of related information.

Electronic display boards erected on urban highways are further examples of technology-based warnings. These massive signs are erected for the purpose of alerting drivers of the road conditions ahead. These displays could improve comprehension of traffic conditions by giving additional information such as the approximate delay duration or provide alternate routing. Also, advanced navigation systems in vehicles could potentially receive this information wirelessly to the vehicle.

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., Wogalter et al, 1998). For example, in many cultures the color red is generally understood to connote greater hazard or urgency than orange or yellow, which in turn are colors that connote higher hazard than other colors, such as blue or green. Thus, in applications the color displayed 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).

Tailoring the warning message to user characteristics such as their experience level can also benefit comprehension. Technology could be used to warn users who are insufficiently skilled to prevent them from using certain equipment. Detection of expertise level could involve some of the sensor methods already described. 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 might initially receive only the basic information, but over time, as their expertise develops, they would receive more and different information.

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, and 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 showing a model carrying out the correct behavior than with a static warning sign instructing the same behavior (Racicot and Wogalter 1995). 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). Unambiguous presentations should reduce cognitive load and decrease misunderstanding that might result in incorrect procedures.

Personalized warnings can also benefit the performance of compliance behavior. Personalized warnings that incorporate the receiver's name 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 is that incorporating the user's name adds relevance to the individual.

CONCLUSION

Future technology-based warning systems offer the promise of providing improved access to safety information and cognitive support for different stages of human information processing. The goal of improving user safety can be accomplished by capitalizing on the interactive and dynamic capabilities of technology and its potential ability to give warning information when and where it is needed.

This plenary is an overview of some of the ways technology-based warning systems can be implemented to benefit warning effectiveness. The main purpose is to describe some of the potential benefits of technology and to provide direction for future warning development and research.

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