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# Using technology to facilitate the design and delivery of warnings

M. S. WOGALTER* and V. C. CONZOLA

*This paper describes several ways in which new technologies can assist in the design and delivery of warnings. There are four discussion points: (1) current product information can be delivered via the Internet; (2) computer software and hardware are available to assist in the design, construction, and production of visual and auditory warnings; (3) various detection devices can be used to recognize instances in which warnings might be delivered; and (4) a warning presentation can be modified to fit conditions and persons. Implications, example applications and future prospects of these points are described.*

## 1. Introduction

Computers and computer-based technologies have changed how tasks are performed at work and in other activities. Technology has enabled the conceptualization and production of many new types of products and altered the environments in which these products are used. Some of these new products and environments pose hazards that are not readily apparent or obvious. When hazards cannot be eliminated through design or controlled by effectively guarding against them, people need to be warned and instructed on how to avoid being injured or property damaged.

Warnings are usually delivered via various printed media such as sticker labels, posted signs or placards, product manuals, package inserts, etc. However, warnings encompass a much larger domain of communications that includes sound, video, and other modal and media channels. Technology has made it possible to produce and control warnings electronically. This paper describes some of the ways new and emerging technologies can enhance the effectiveness and facilitate the dissemination of warnings.

## 2. Delivery

When products and equipment are purchased new they are typically accompanied by paper documentation such as owner's manuals and safety instruction sheets, which usually include one or more warnings. Often these materials are thrown away or placed in a location separate from the product (Wogalter *et al.* 1998b). Unfortunately, when a product subsequently requires repair or maintenance, the owner's manual sometimes cannot be located. Moreover, when products and equipment are purchased used, the original documentation is sometimes not included. Thus, important safety and warning information may not be available when it is needed. Consumers could contact the dealer or manufacturer to send a replacement manual, but this process can be costly in terms of time, effort and money. Because of these costs, people may not request a replacement manual, and even if they do, the manual might not be received before the equipment has been used in an unsafe manner. Over the past few years, the growth of the Internet has provided an alternative means by which important product information can be made available (Young *et al.* 2000). Many manufacturers now post product documentation on their websites so that consumers can view the information or print it for later review. This capability also provides the opportunity to make corrections, modifications and updates to the information that originally accompanied the product.

Currently, most computer software and hardware is accompanied not only by hard-copy documentation, but also by a computer disk or CD with more current documentation in soft-copy form. In addition, the hard-copy documentation usually includes a reference to the company's website where consumers can access the latest product information. Some companies even provide utilities that automatically retrieve software updates from their website. Other companies allow customers to register to receive e-mail bulletins about product

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Ergonomics Program, Psychology Department, 640 Poe Hall, CB 7801, North Carolina State University, Raleigh, NC 27695-7801, USA.

* To whom correspondence should be addressed. e-mail: wogalterm@aol.com

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updates and other information. These methods suggest alternative means by which manufacturers might deliver important safety-related information to consumers. For example, if a drug company became aware of a dangerous side-effect that was unknown at the time the drug was released, it could e-mail registered customers to alert them of updated safety procedures.

Through the Internet, manufacturers can provide current documentation for both newer- and older-model products. Over time, products evolve so that newer models might be substantially different from older ones. To deliver the appropriate information, the entire information base could be compartmentalized and tagged so that appropriate sections of the database can be selected for retrieval. Given the product model and/or serial number, relevant information can be accessed for the owner's particular product. In practice, this may mean including parts of the original documentation and some newer updated information substituted for outdated documentation. Information about irrelevant features (those not in the owner's particular product) would be eliminated before the download. The benefit of such a system is a reduction of the total material obtained by users. Because people tend not to read voluminous amounts of text, limiting the download to only the relevant information shortens the length, making it more likely the material will be read.

Another benefit of Internet delivery is that information can be supplied world-wide, in different languages, enabling greater dispersion of the material. For example, a product could have labelling with a section that lists Internet addresses or toll-free fax-back telephone numbers to obtain information in different languages. In addition, inexpensive devices are now available that read bar codes representing Internet addresses. The availability of these inexpensive bar code readers could help consumers gain access to relevant product information via the Internet.

While the Internet has provided a means to deliver product information and warnings when the instruction manual is not available, currently viewing and downloading this information requires a wired connection to the Internet. A wired connection may not be available when information is needed, such as in a remote setting or a hazardous situation that was not expected. The growth of wireless networks and the widespread use of wireless devices like cellular telephones and PDAs may eliminate this problem. Within the not so distant future, wireless network access points will proliferate to the point that continuous connection to the Internet through wireless devices will be possible. Empirical research (e.g. Frantz and Rhoades 1993, Wogalter *et al.* 1993a) has shown that warnings are more effective when delivered proximate to the hazard. By delivering information through a PDA or cellular telephone, information can be made available directly at the point of use. For example, consider a driver who needs their vehicle's battery jump started in a remote location and who does not have access to the product manual describing how to perform this potentially hazardous procedure safely. A driver with wireless access to the Internet through a PDA or cell phone could view the jump-starting instructions from the automobile manufacturer's website directly at the point of use.

Beyond the Internet, other computer-based, information delivery mechanisms are now available that could be used to present warnings to certain groups of users or in certain environments. The rapidly improving technologies of optical character recognition (OCR) and synthesized/digital voice presentation allow for voice presentation of warning information. OCR devices are capable of 'reading' aloud printed text from paper, while screen reading software performs a similar function on text displayed on a computer screen. In addition to assisting blind or visually impaired persons, these technologies could also benefit non-visually impaired individuals by providing information in a salient, attention-getting form. Voice presentation would also benefit those who would not otherwise read the material. Conzola and Wogalter (1999) created a 'talking box' for a computer peripheral device that, when opened, vocalized several precautions about the proper installation of the device. Participants who were presented with the voice precautions were more likely to carry out the precautionary behaviours than those who were only provided the precautionary information printed on the box or in the product owner's manual. While this study showed a clear benefit of voice warnings, it should also be considered that voice warnings might sometimes annoy users.

## 3. Design

Typically, environmental warning signs posted in buildings and other environments are purchased from retail establishments, mail-order companies or through catalogues of prefabricated signs. Sometimes, safety departments in larger companies produce signs for internal use. Now computers, colour printers and consumer desktop publishing software enable the development and construction of warning materials by anyone. In addition, in recent years specialized 'canned', warning design, software programs have been offered by various vendors. These programs produce warning designs based on (1) Occupational Safety and Health Administration (OSHA 1994) rules which US employers must use to protect their employees and (2) the American National Standards Institute's (ANSI 1998) safety warning standard (colour, sign, symbol, label and tag), as well as other warning design sources. Such

specialized software programs can quickly produce signs that comply with existing regulations, standards and guidelines. However, they might not produce the combination of components needed in a sign. In other words, they often lack flexibility. For example, these packages may lack the ability to produce designs, which might be needed in specialized situations that do not comport with current regulations and standards. Alternatively, they might include only a restricted set of pictorial symbols. Greater flexibility is enabled when warnings are produced using more generalized graphics software that allows a multitude of design components (e.g. pictorial symbols) to be imported into the warning from other sources. The software should allow designs that can be iteratively modified until an acceptable design is achieved. Wogalter *et al.* (1999) describe a methodology for rapidly prototyping and testing warnings based on principles of software development and usability testing.

Although technology has made it easier to produce warning materials, it does not necessarily follow that the warnings produced will be effective. The effectiveness of the warnings produced will likely be based on the designer's knowledge of (1) the hazard, (2) associated aspects of the situation, (3) warning design principles and (4) characteristics of the target audience. These factors are important regardless of the use of computer tools in the design process.

## 4. Detection

Computers can be used in conjunction with detection and sensing devices (1) to detect when an animate or inanimate target is present, and (2) to detect when a hazard is present. Such detection methods are discussed in the next two sections.

### 4.1. *Presence of a target*

Numerous kinds of detection devices are available to sense the presence of a person, animal, vehicle or other types of harmful stimuli. These include photoelectric beam interruption, and motion, heat and weight detectors, among others. Wogalter *et al.* (1993b) used an infrared photoelectric detection device to initiate warning presentation when individuals entered a high-risk area. Connected to a computer and with appropriate programming, a detection system can be used to control the presentation of warning information. Future, more sophisticated systems could be used to identify specific targets. For example, automotive vehicles could be made identifiable by sensing the license plate information or by transmitting signals that could be picked up by sensing devices in or around the roadway. The vehicle's history could be accessed, and then certain warning information could be presented to the motorist. The information could be transmitted to an external electronic sign or to an on-board presentation system (e.g. a navigation or radio receiver system). GPS devices could be used to present warning information relevant to the vehicle's location, speed and heading. Likewise, individuals could be tracked in ways similar to the vehicular examples described above. Individuals carrying these sorts of systems in miniaturized form could relay information on identity and associated personal characteristics and preferences. With the appropriate sensing input, computers could process this information and then present warnings specifically designed for the person. Wogalter *et al.* (1994) discussed how relevance plays a role in warning effectiveness. They provide empirical results showing that a personalized warning (using an individual's name) was more effective than an impersonal warning (using the signal word 'Caution' instead of the name).

In addition to detecting the presence of a specific target for warning information, technology might also be used to promote the safe use of hazardous products by restricting their use to a certain individual or group of individuals (e.g. through biometric identification built into the device or tool). Such a system would prevent the product's use by unqualified or unauthorized individuals. For example, electric power tools could incorporate interlocks based on fingerprint or handprint identification that would prevent them from operating except when held by registered individuals. Systems incorporating similar biometric technology are used today to limit access to restricted or hazardous areas in government and industrial settings.

### 4.2. *Presence of a hazard*

Combining the GPS technology described above with wireless Internet access could provide a powerful hazard detection and warning delivery system. GPS systems could also be used to track the location of moving hazards such as vehicles transporting hazardous waste. Alerts could be sent to authorities if the location of the hazard was not as expected.

Detection devices could also be used not only to sense the presence of an at-risk target, but also to sense the presence of a hazard. For example, moisture detectors could be used to signal the presence of ground saturation. This information, combined with information on the occurrence or potential occurrence of heavy rainfall, could be used to indicate the need for a flash flood watch or warning.

## 5. Dynamic modification

In contrast to static signs or labels, computers allow warnings to be changed. Computers allow the flexibility of dynamically changing warnings' (1) physical characteristics and (2) message content. Such changeability reduces the potentially negative effects of habituation and allows for personalization of warnings. These aspects are discussed below.

### 5.1. *Physical change*

A major correlate of warning effectiveness is perceived hazardousness. People are more likely to read warnings on products that they believe are more hazardous than those that they perceive to be less hazardous (Wogalter *et al.* 1991). Hazard perceptions can be influenced by the warning's visual (Wogalter *et al.* 1998a) and auditory (Barzegar and Wogalter 1998, Weedon *et al.* 2000) characteristics. For example, adding red, orange or yellow to a black-and-white warning sign increases the level of perceived hazard relative to adding the colours blue or green (Smith-Jackson and Wogalter 2000). Dynamically changing the colour of a warning on an electronic display screen could be used to signal a changed level of danger. Combinations of features, such as combining different colours with different signal words could be used to calibrate the level of the hazard appropriate to a given situation (Braun *et al.* 1994). Likewise with computer-controlled auditory displays, sounds and voices with certain characteristics could generate different levels of urgency that are appropriately mapped to the hazard level involved (Weedon *et al.* 2000). Furthermore, the sound and voice characteristics could be changed as appropriate to fit the actual hazard level (Hollander and Wogalter 2000).

### 5.2. *Message content*

Computers can also control the message content presented. On many busy, urban, highways large electronic display boards have been erected to alert motorists of conditions ahead. Sometimes hazardous conditions are described and alternative routes are suggested. In their current form these signs present only textual information that might be missed by individuals travelling past the signs at a high rate of speed. The inclusion of graphical symbols on such signs would make them more likely to be noticed and could communicate the necessary information at a glance, making reading unnecessary. Bruyas *et al.* 1997 makes recommendations for the design of graphical symbols with minimal features that could be used on such displays. As the cost of large, high-resolution, flat screen, video displays decreases, their use as changeable signage will likely increase, thereby allowing more detailed graphical symbols to be used.

An evolving technology that has potential for presenting dynamically changing warning content is electronic paper. Electronic paper is a very thin, high resolution, low power, electronic display technology that shares many of the physical characteristics of paper. It can be written to dynamically like traditional computer displays. However, its light weight and flexibility make it useful for applications where the cost, size, weight or power requirements of computer displays precludes their use. While not rugged enough for use in outdoor applications, electronic paper could be used in commercial and industrial environments as a medium for delivering dynamic warning information. For example, a single electronic paper sign with a rotating message could be replace numerous printed signs alerting workers to noise, airborne particle and respiratory hazards in a factory setting.

### 5.3. *Habituation*

As stated previously, the physical characteristics and message content of a warning can be changed dynamically to fit the level of risk. Another reason for changing a warning is to compensate for cognitive changes in individuals over time (e.g. from experience). For example, once a person is exposed to a given stimulus repeatedly, less attention is given to this stimulation upon subsequent exposures; this is called habituation. If the desire is to lengthen the duration of a warning's stimulus value in gaining attention, the warning should be changed over time. A dynamic computer controlled warning could do this. Warning modifications can be based on what people see or hear depending on the conditions. For example, a warning that states 'Bridge freezes before the road' is intended to warn people about icy road conditions on bridges in very cold weather. However, the sign is sometimes permanently installed and visible in summer conditions when freezing is irrelevant. Together with temperature detection devices, the sign could present the information only during cold weather conditions. More sophisticated systems could identify particular persons to 'individualize' the warning (Wogalter *et al.* 1994). For example, if a sign has already been presented to a person earlier, the warning could be changed in subsequent presentations.

## 6. Conclusion

In this paper, ways in which technology can be used to assist in the communication of warning information are discussed. The topics include delivery, design, detection and dynamic modification. Currently available technologies and likely future developments are mentioned.

The promise of more effectively delivered hazard communication is envisioned. In the future, there will not necessarily be more warnings, but rather better, more effective warnings. These are warnings delivered at the proper time and appropriate place under applicable conditions befitting the target.

Although this paper has dealt with computers and warnings, there are aspects of these two domains that this paper did not discuss — in particular, the use of computers in warning research. Computers have been used in different ways to conduct (e.g. Cox *et al.* 1995), collect (e.g. Bzostek and Wogalter 1999) and analyse data (e.g. Cox *et al.* 1997). Research methodology involving warnings and computers is necessarily a topic for another paper.

As we look toward the future and the use of technology to deliver warning information we must be cognisant of the problems such systems might cause. One potential problem that must be considered is the issue of access to technology. Currently, not all segments of the population can afford or have access to technologies like the Internet and wireless communication devices. This so-called 'digital divide' has the potential to leave some people at greater risk to hazards than others. Therefore, it is important that technology based warning systems not replace existing delivery mechanisms, but rather supplement them. In the future, these and other technologies may reach the vast majority of the world's population just as clocks and transistor radios have become ubiquitous today.

Another potential problem with technology based warning systems is the invasion of individual privacy. While the types of detection systems described here would benefit people in terms of their knowledge of hazards and how to avoid them, these systems have the potential to be intrusive. The balance between privacy and security is an issue that will receive much attention in the years ahead, not just with respect to warnings but in other areas of life encroached by technology.

Lastly, there is one other issue related to computer-aided delivery of warnings that has not been discussed directly except by implication. This is the issue of warning intrusiveness. Warnings by their nature need to be attention getting. A warning that fails to get the attention of a person at risk can lead to extremely severe consequences. Edworthy and colleagues (e.g. Edworthy *et al.* 1995, Edworthy and Adams 1996) advocate matching the urgency of the warning to the dangerousness of the situation. False alarms, attempts to turn off the warnings, and habituation might be diminished by effectively matching the situation with the urgency of the warning. The actualization and operationalization of such mapping could be performed using computers, sensors and software that assess sensor input together with the appropriate database to decide what degree of warning intrusiveness is needed. Electronic detection and tracking in hazardous workplaces and public roadways is probably possible, but implementation in home and personal environments may not be. While one ponders how intrusive we would like warnings to be, it is interesting to note that advertisements have been historically much more intrusive than warnings. Arguably, given the importance of injury and disease prevention to individuals and society, the reverse should probably be true.

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