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12 Analysis and Design of Warnings in the Workplace

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CONTENTS

INTRODUCTION

Work is an integral component of human society. Much, if not most, of the world population spends a large portion of its waking hours in the workplace setting (U.S. Bureau of Labor Statistics, 2012). Not surprisingly, job satisfaction and productivity are linked to life satisfaction (Keon and McDonald, 1982). Given this connection, one main objective of the ergonomics/human factors (E/HF) discipline includes enhancing workplace productivity and safety (Sanders and McCormick, 1993). One approach to achieving this objective includes the development and strategic use of effective warnings as a means of communicating safety-related information to workers. This chapter focuses on the factors that influence warning effectiveness within the workplace using the communication-human information processing (C-HIP) model. Not only does this model serve as an effective means to review the warnings literature, but it also can be used as a predictive tool to understand why certain warnings fail.

Defining the Work Setting

Any work setting in which we may find hazards and/or warnings varies considerably based on a number of factors such as geographic location, the type of work being performed and the characteristics of the workforce, to name but a few. The workplace of a factory assembly line worker may greatly differ from the workplace of a university professor; yet some commonalties exist to inform E/HF practitioners how manipulations of warning characteristics can generalise to many workplace contexts. To understand the complex interactions that occur between people, equipment, tasks and environments within specific settings, a standard practice in the field of E/HF is to apply a systems approach (Helander, 1997). Thus, a work system environment includes a variety of elements such as the working person, the work task, operating resources and the work environment (Luczak et al., 2006 and see Chapter 1 of this book). A working person can be described using a variety of dimensions such as the physical capability to perform work, including functional limitations as well as the psychological dimension of willingness to perform work. In the case of the assembly line worker, it might be important to note physical limitations that could influence work, such as a lower back injury that prevents the lifting of objects weighing in excess of 30 lb. Likewise, the university professor might be differentially motivated to achieve one task (e.g. writing a journal article) instead of another (e.g. attending a faculty meeting).

Work tasks can be defined as the step-by-step procedure for fulfilling an objective, whereas operating resources include the equipment needed to perform the work. In the case of the assembly line worker, equipment such as a drill press and other tools might be used in the task of machining automobile parts, whereas the university professor might operate a scanner and desktop computer to document travel receipts. Finally, the work environment includes the social and cultural factors as well as the physical attributes of the environment where work is performed. Differences in the workplaces of the exemplar assembly line worker and professor might include the amount of lighting available as well as the presence of excessive noise from equipment and other personnel. The social differences in a workplace environment might be seen in, for example, institutional differences in the *safety culture* demonstrated by groups of workers that might encompass basic assumptions, attitudes or values regarding organisational safety concerning potential hazards in the workplace (Marquardt et al., 2012).

Hazard Hierarchy

Different degrees of safety culture can exist between organisations such that one could have a very low, almost fatalistic level (e.g. 'accidents are bound to happen on the job') and another has a high level ('we are proactive in solving safety problems before they arise'; see Parker et al., 2006). Consistent with the more proactive approach to hazard mitigation, a well-accepted general hierarchy of hazard control is often associated with efforts to reduce hazards (Laughery and Wogalter, 2006; Lenorovitz et al., in press). It includes several fundamental strategies or approaches that can be employed to limit occupational risks. The first and best strategy for controlling hazards is to design them out – to eliminate them. For example, if a traditional manufacturing process requires the use of toxic chemicals to create a product, an employer might seek alternate manufacturing procedures that utilise non-toxic chemicals. Sometimes the hazard cannot be completely eliminated without ruining the functionality of the product or otherwise impacting quality, so a second-level strategy of hazard control, guarding, should be considered. With guarding, the hazard remains present, but there is a barrier to separate the worker from the hazard to prevent harm. A guarding method might employ a better way to keep the toxic chemicals from coming in contact with workers. For instance, the manufacturing steps that require the use of toxic chemicals might be conducted when workers are isolated in another room; alternately, if workers have to be present, they might be outfitted with protective clothing.

Warnings are the third strategy of hazard control. Only when the strategies of designing out or guarding are not feasible or practical should warnings be the chosen method of controlling hazards. Design and guarding methods should be considered, tested and used if they reduce hazards and do not dramatically hurt functional utility. Also, even with design and guarding changed, warnings might still be needed if the workplace hazards remain after design and guarding considerations have been made and any enactments of them have taken place. In general, good design and guarding are better methods of hazard control than warnings. Indeed, warnings are properly viewed as a supplement, not a substitute, to other approaches to safety (Lehto and Salvendy, 1995). Therefore, if the goal is to protect workers from harm, when the hazard has not been controlled by design/guarding, then the warning system needs to be designed to maximise its effectiveness so as to influence people's perceptions, cognition and behaviour.

Purpose of Warnings

Warnings in the workplace serve three main purposes (Conzola and Wogalter, 2001). First, warnings are used to improve safety by reducing the likelihood of workplace accidents that might result in death, personal injury or property damage. Second, they are used to communicate important safety-related information to a target audience such as workers or others (e.g. visitors) present in the workplace. In general, warnings should include a description of the hazard, instructions to avoid the hazard and the consequences that might occur as a result of not complying with the warning (Rogers et al., 2000). Finally, warnings are used to promote safe behaviour and reduce unsafe behaviour. For example, warnings might serve to remind employees of their previous safety training where they were instructed to don personal protective equipment such as earplugs or face shields (Leonard et al., 1999).

Recognised Challenges of Warning Design and Evaluation

While the need for effective workplace warnings should be apparent, a number of challenges may slow or even prevent the deployment of warnings that can protect worker safety (Laughery, 2006). For instance, as international trade grows, the increasing diversity of workers will make it difficult to design a warning that addresses the needs of all individual workers. Consider a workplace where people speak multiple languages, have different literacy levels and have different cultural values. It is almost the Herculean task of a warning designer to develop a warning that identifies the hazard and promotes safe behaviour by informing workers how to avoid being injured or killed. Once such a prototype warning is developed, it should undergo an iterative process that includes rigorous evaluation and redesign whereby observed shortcomings in earlier warning design are corrected as the design is updated (Mayhorn and Goldsworthy, 2009).

WARNING SYSTEMS

When asked to consider the concept of a warning, many individuals take a very narrow view and believe that safety information is transmitted solely as a static sign or a portion of a label (Laughery and Wogalter, 1997; Wogalter and Mayhorn, 2005). In Figure 12.1, a label is attached to a piece of industrial equipment that poses a heat hazard that might result in a fire or a thermal burn. While this component is certainly important, it is often necessary to broaden the transmission of safety information to include several components in the form of a warning system that utilises a variety of media and messages (Laughery and Hammond, 1999).

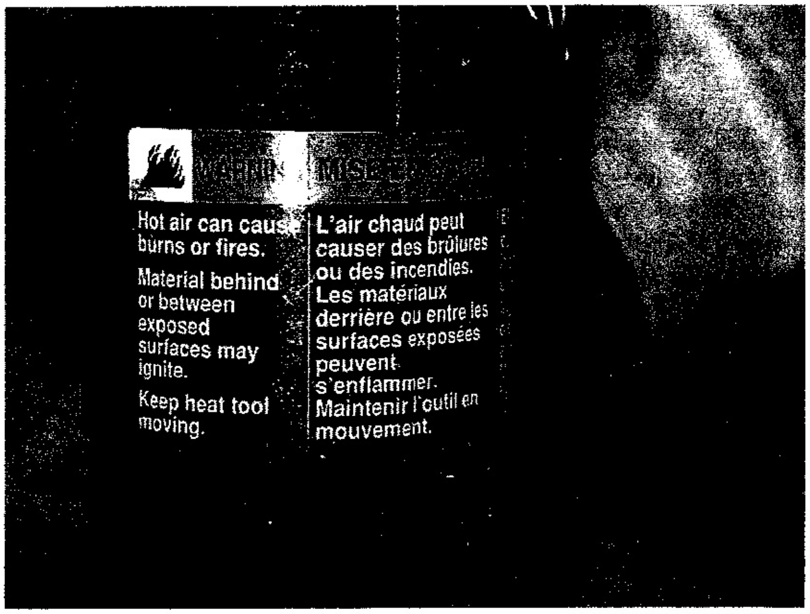

FIGURE 12.1 Warning on a heat gun. (From Richard M. Hansen & Associates, Inc., Lombard, IL, File No. 98-446.0244, 12 May 2000.)

Components

Warning systems usually contain multiple components. For example, consider the warning system designed to assist mechanics in the matching of automobile tyres and rims where the consequences of a mismatch could result in explosive tyre decompression leading to the death of a motorist. Components of this tyre warning system may include the raised lettering on the side wall of tyres, tread labels on new tyres, stickers or stamping on the rim, safety-related wall posters in shops where tyres are mounted, statements in rim and tyre catalogues and manuals, verbiage in documentation accompanying sales receipts of tyres and rims, reminder pop-up messages in point of sales electronic workstations and verbal statements from employers and other employees. It should be noted that these components may not be identical in terms of content or purpose. For instance, some components may contain minimal content and be intended to capture attention so that it functions to direct a person to another component that includes more comprehensive information. An example is the statement 'See the Michelin Fitment Guide', which might be included on a handout to remind tyre professionals that they can accurately match the tyre size that is appropriate to a particular rim by accessing this comprehensive manual.

Because workplaces differ, some components of warning systems may be unique to certain settings. For instance, different components may be intended for different target audiences. Within agricultural settings, warning components that accompany pesticides might include printed on-product labels, verbiage in advertisements about the product, verbal statements from the salesperson to the buyer as well as material safety data sheets (MSDSs) which include sophisticated chemical information regarding the product. In this instance, the on-product warning is intended for everyone who comes in contact with the pesticide including a farm worker, whereas the MSDS is directed to a safety professional working for the employer. Thus, informational content will differ due to different purposes of the information and the characteristics of the target audiences.

Work Settings

In the workplace as opposed to home or other non-workplace environments, there is control over what people do. Employees are different than non-employee personnel because employers have contractual arrangements that can affect what they can do. Employers in the workplace can control many aspects, including providing safety training. They can potentially train workers about everything they do. In the United States, the Occupational Safety and Health Administration (OSHA) is a government agency tasked with enforcing workplace safety. Although OSHA requirements mandate the need for regular safety meetings, it is unclear how the quality of those training sessions can be assessed. Some employers undoubtedly have very good training, but smaller organisations that employ fewer workers may not have the time or resources to do everything (paperwork included) effectively. Manufacturers need to expect that employers may not be able to take much effort to train their employees about every hazard to which they may be exposed. Product and equipment manufacturers need to provide to businesses and government agencies, etc. materials that make it easy to train workers to be productive, satisfied and safe.

Based on this discussion, it is clear that a working person often relies on others as resources to provide appropriate components within a warning system. As the concept of *cascading responsibility* described by Williams et al. (2006) suggests, multiple parties are involved in the dissemination of safety information. In the case of a tree removal specialist, an employee might be tasked with using a woodchipper to clear debris, and he or she is dependent on a number of entities to provide safe job-related instruction. Employers/supervisors should provide adequate training to promote safety in the field. Such training could include a formalised set of courses, basic *hands-on* training, regular safety meetings or the provision of written policy documents that describe operational procedures. Moreover, these individuals are charged with direct supervision of an employee such that they can monitor safety performance and intervene should the employee deviate from safety protocols. In the United States, employers are responsible for workers' safety, and employees are prevented from suing employers for negligence for almost any reason because federal government laws – workman's compensation laws – prevent lawsuits and have a different method of compensation.

Because employees and employers interact with equipment such as the aforementioned woodchipper, they are dependent on the manufacturer of this device to provide instructions for safe use. Manufacturers know or should know more than other parties about the potential hazards accompanying the use of their product, so they are tasked with employing the hazard hierarchy during product design. If alternate designs cannot be used to eliminate hazards, manufacturers must include appropriate safeguards in their design and disseminate safety information and instructions. Such information might include warnings in a variety of components such as MSDSs, informational inserts/pamphlets, owner's manuals or on-product labels. For example the exterior of a woodchippper that was literally covered with stickers included the following safety text:

> DO NOT attempt to operate the machine without proper training and becoming very familiar with the operator's manual. The hydraulic feed wheels are designed to pull wood into the chipper. They do not know the difference between a hand and wood. If a guard is removed, it must be replaced or severe injury can result. The cutter-wheel coasts for several minutes after the power is shut down. DO NOT attempt any maintenance while the wheel is turning. NEVER open or close the cutterwheel cover while the disc is still turning.

When purchasing equipment for use in the workplace, most employers do not deal directly with manufacturers. Instead, employers may interact with intermediaries such as distributors or retailers. For instance, the woodchipper manufacturer may sell its product to distributors who then employ retailers to sell their products to the employer. In such a situation, the manufacturer must be certain that safety information is passed to the distributor who in turn passes the information to the retailer who communicates directly with the employer/buyer. If at any point in the chain of commerce safety instructions are lost, the end user (employee or subcontractor) might be placed at the risk of injury or death. If a manufacturer then dutifully provides the appropriate on-product warning labels but a distributor or retail entity decides to paint the exterior of the woodchipper for aesthetic reasons, safety information may be covered, and end users may not be informed about the hazard.

Unlike the case with employers mentioned earlier, injured users in the United States can sue the distributors, retailers and manufacturers of the equipment for irresponsible design, guarding and warning. So potentially, any of the entities in the line of commerce such as product and equipment manufacturers, retailers and distributors can be found negligent for failing to provide necessary warnings and instructions to the employer and the employee.

Given the potentially lethal consequences that occur when a hazard is not adequately communicated to workers, the design and evaluation of effective warnings are critical. As the contents of this chapter will demonstrate, E/HF professionals face a number of challenges in creating and deploying warnings. Not only must they consider relatively mundane issues such as where to place warnings on products or how to disseminate safety education materials but they must also determine how information should be presented in the particular context of a workplace to multiple stakeholders who vary considerably. Thus, it is necessary to understand how workers process warning information based on fundamental cognitive principles as a means to addressing the real-world problem of safety in the workplace.

C-HIP MODEL

In this section, the C-HIP model is presented to serve as an organising framework for reviewing some of the major concepts and findings regarding factors that influence warning system effectiveness (Wogalter, 2006b). Specifically, this chapter reviews research of some of the influential factors found at each stage. After going through the stages of the model, another benefit of the C-HIP model is described, namely, it can serve as an investigative tool for helping determine why a warning failed to be effective.

The C-HIP model has two major sections, each with several component stages. A representation of the model can be seen in Figure 12.2. The first section of the framework employs the basic stages of a simple communication model. Here the model focuses on a warning message being sent from one entity (source) through some channel(s) to another (receiver).

The second major section of the model focuses on the receiver and how people internally process information. This section interfaces with the first through effective delivery of the warning to individuals who are part of the target audience. When warning information is delivered to the receiver, processing may be initiated and, if it is not blocked in some way, will continue through several stages: from attention switch, attention maintenance, comprehension and memory, beliefs and attitudes, motivation and possibly ending in behaviour. Similar information processing models have been discussed by others (Lehto and Miller, 1986; Rogers et al., 2000).

The C-HIP model is both a stage model and a process model. The model is useful in describing a general sequencing of stages and the effects warning information might have as it is processed. If information is successfully processed at a given stage, the information *flows through* to the next stage. If processing at a stage is unsuccessful, the flow of information will not reach to the next stage. If a person does not initially notice or attend to a warning, then processing of the warning goes no further. However, even if a warning is noticed and attended to, the individual may not understand it, and as a consequence, no additional processing occurs beyond that point. Even if the message is understood, it still might not be believed, thereby causing a blockage to occur at this point. If the person believes the safety message, then low motivation (to carry out the warning's instructed behaviour) could be a cause for a blockage. If all of the stages are successful, the warning process ends in safety behaviour (compliance) attributable to the warning information.

Although the model tends to emphasise a linear sequence from source to behaviour, there are feedback loops from later stages in the process which can impact earlier stages of processing, as illustrated on the right side of Figure 12.2. For example, when a warning stimulus becomes habituated from repeated exposures over time, less attention is given to it on subsequent occasions. A more specific example could be given in terms of prescription pharmaceuticals (Guchelaar et al., 2005). If a new hazard is added to a warning, a pharmacist may not notice it if he or she had previously prescribed and read the previous warning version in the past. Here, memory and experience affect

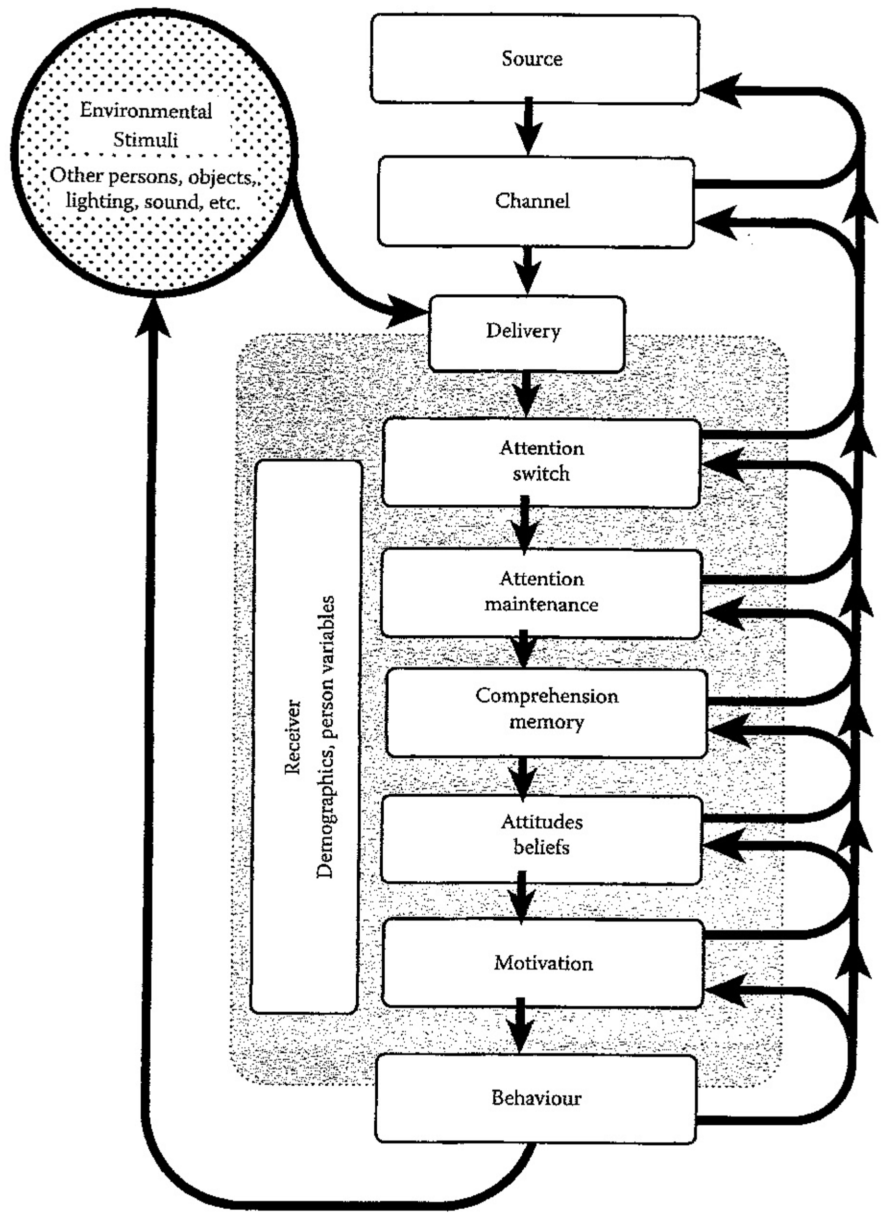

FIGURE 12.2 C-HIP model.

an earlier attention stage. A second example of feedback effects concerns the influence of beliefs on attention. Some individuals may not believe that a given product is hazardous and, as a result, not think about looking for a warning. Thus, if a pharmacist or other health-care professional believes that a commonly prescribed analgesic can cause no harm, they will be less likely to read a warning about newly found drug interactions (Russ et al., 2012). Thus, a later stage, beliefs and attitudes, affects an earlier stage of attention.

In the following sections, factors affecting each stage of the C-HIP model are described. The first three sections concern the communication features of the C-HIP from the source via some channel(s) to the receiver. Subsequent sections concern analysis of information processing factors that are internal to the receiver.

Source

The source is the initial transmitter of the warning information. The source can be a person (e.g. supervisor, co-worker) or an organisation (e.g. company, government). With respect to the workplace, warning information often does not originate from the employer; instead, the employer may post pre-prepared safety statements/instructions provided by a third party. Because employees often interact with equipment, this third-party source is frequently the manufacturer of workplace machinery (although in cases of imported products, the importer/distributor in the United States may be held responsible) (McGrath, 2011). One critical role that the source assumes is to determine if there are hazards present that necessitate a warning. Such a determination requires some form of hazard analysis (Frantz et al., 1999; Young et al., 2006). If a hazard is identified, the source must first determine if there are better methods of controlling it than the use of warnings, such as eliminating or designing out the hazard or guarding against it using design and engineering procedures (for a comprehensive review, see Laughery and Wogalter, 2006).

There are other considerations such as the specific characteristics of the equipment involved. Some products are inherently more dangerous than others. For instance, a manufacturer of a nail gun will have a different role to play than a manufacturer of a welding helmet. Although even safety-related products such as welding helmets can also have hazards, it remains the responsibility of the manufacturer to mitigate potential risks, which might include the use of warnings.

If the need for a warning exists, then the source (generally the manufacturer) needs to determine how workers should be warned, for example, what channel(s) to use (see later section) and the warning's intrinsic characteristics. In addition, the perceived characteristics of the source can influence people's beliefs, credibility and relevance (Wogalter et al., 1999d; Cox and Wogalter, 2006). Information from a reliable expert source is usually given greater credibility. It is generally assumed that the manufacturer is expert with regard to the product they produce. It is expected that they know or seek to learn about hazards and keep them at bay. That is their role. If the source does not carry out its role satisfactorily, persons can be injured, and in some cases, depending on country and legal jurisdiction, the manufacturer can be sued, fined and the product recalled.

Channel

The channel is the medium and modality in which information is transmitted from the source to one or more receivers. Workplace warnings can be transmitted in many ways. Warnings can be presented in labels directly on equipment, on shipping containers, in user manuals, in package inserts, on posters/placards, in brochures and as part of audio–video presentations in various media such as face-to-face safety meetings or via the Internet. Most commonly, warnings use the visual (text and symbols) and auditory (alarms and voice) modalities as opposed to the other senses. There are exceptions, for example, an odour added to industrial glue to signal the olfactory sense thereby reminding users to ventilate the work area (Hatem and Letho, 1995), and the rough vibration of a product that is not mechanically functioning well which provides tactual, kinaesthetic and haptic sensation (Mazis and Morris, 1999; Cohen et al., 2006).

There are two dimensions of the channel. The first concerns the media in which the information is embedded (e.g. label, DVD video). The second dimension is the sensory modality of the receiver (visual, auditory). Some media involve one modality (e.g. product manual involves the visual sense) and others involve two modalities (e.g. DVD or WWW videos often have both visual and auditory). Visual presentation can be comprised of both or either text and symbols. Auditory presentation can be nonverbal (noise, beeps, buzzers) and verbal (voice/speech) sounds. For example, traditional smoke alarms or carbon monoxide detectors produce nonverbal signals.

Multimodal warnings may be more effective in promoting safety behaviour than warnings that utilise a single modality because they provide redundancy (Baldwin et al., 2012). If an individual is not watching a visual display, he/she can still hear it (Wogalter and Young, 1991; Barlow and

Wogalter, 1993). If the individual is blind or deaf, the information is available in the other modality. In addition, if an individual sees and hears warning information, there is a greater likelihood that the message will be delivered to otherwise vulnerable receivers (e.g. both deaf and blind persons will be satisfied, and persons overloaded in one modality could receive it in another modality). Also there is well-supported theory in cognitive psychology and education that multimodal presentation enhances learning because the information is richer and may link to greater or better internal representational nodes (Paivio, 1971; Clark and Paivio, 1991).

Longer, more complex messages may be better presented visually because reading language is generally faster and allows easier review and re-review of the material. However, shorter, less complex messages presented aurally can be more effective than the same messages presented visually. Also, the presentation of an auditory signal is generally better for switching attention (a stage described earlier). An implication from this analysis is that a short auditory warning pointing to more detailed information accessible elsewhere would be beneficial for capturing attention as well as enabling the processing of longer and more complex information.

Delivery

While the source may try to disseminate warnings in one or more channels, the warnings might not reach some of the targets at risk (Williamson, 2006). Delivery refers to the point of reception where a warning arrives at the receiver. To emphasise its importance, it is shown as a separate stage in the current C-HIP model shown in Figure 12.2. A warning that a person sees or hears is a warning that has been delivered. A safety video that is produced by a tool manufacturer but never reaches the workplace would constitute delivery failure. The reason for the failure to deliver the warning to targeted individuals can be multiple. The video may be sitting in bulk boxes in a warehouse and not have been distributed because the manufacturer's ordering procedure requires that an employee must actively request the information. Or the distribution could be haphazard, reaching some intended persons and not others. But even if individuals receive the video, they may not receive the needed information. They may not have the time or playback equipment to see it. Of course, even if the person does see the video, it may not include the necessary warning. Thus, it may be necessary to distribute warning information in multiple ways to reach receivers at risk.

Environmental Stimuli

Besides a given workplace warning, other stimuli are almost always simultaneously present. They may be other warnings or a wide assortment of non-warning stimuli. These stimuli compete with the warning for the worker's attention (described further in text). With respect to a given warning, these other stimuli may be described as *noise* that could potentially interfere with warning processing. Several examples can illustrate. A co-worker's cellular phone ringing just when an individual begins to examine a warning may cause distraction and lead to the warning not being fully read. Likewise an abraded, scratched warning from considerable use and environmental exposure could prevent a newly hired worker from reading the warning on the pneumatic nail gun illustrated in Figure 12.3. The environment can have other effects. The illumination can be too dim to read the warning. In such cases of distraction or legibility, another warning of greater salience could have the capability to attract and hold a person's focus.

Environmental influences can also include other people. Awareness of what others are doing in the local environment and elsewhere can affect warning compliance both positively and negatively (deTurk et al., 1999; Olson et al., 2009). Seeing co-workers wearing hard hats at a construction site suggests it is proper behaviour to wear them. But instances of seeing others not wearing goggles, gloves or other needed protective equipment while using a hazardous tool

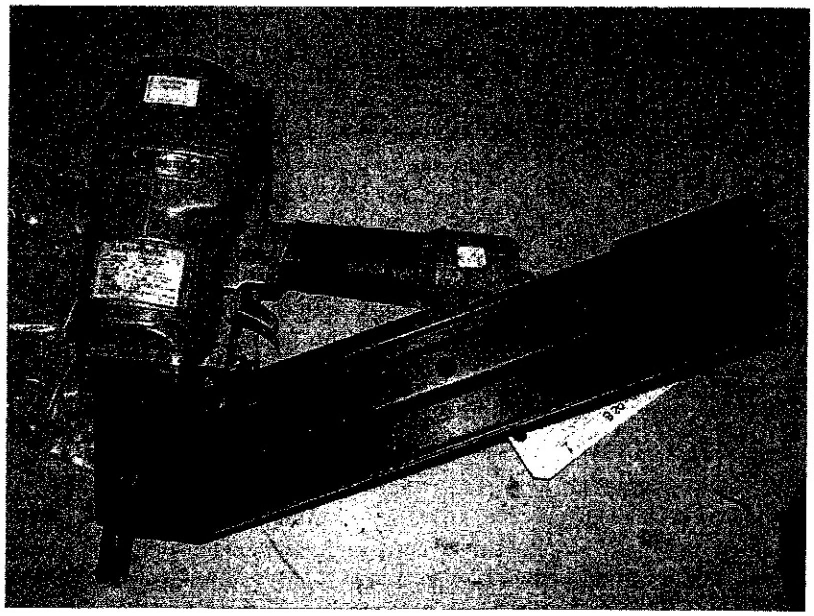

FIGURE 12.3 Pneumatic nail gun warning.

can suggest that such protection is not needed, even though the other safety information such as a product warning states that it is required (Wogalter et al., 1989).

Receiver

The receiver is the person(s) or target audience to whom the warning is directed. In the context of the workplace, receivers can be the working person as well as supervisors and others (e.g. visitors) who are exposed to the hazards. For a warning to effectively communicate information and influence behaviour, the warning must first be delivered. Then, attention must be switched to it and maintained long enough for the receiver to extract the necessary information. Next, the warning must be understood and must concur with the receiver's existing beliefs and attitudes. Finally, the warning must motivate the receiver to perform the directed behaviour. The next several sections are organised around these stages of information processing.

Attention Switch

An effective warning must initially attract attention. To do so, it needs to be sufficiently salient (conspicuous or prominent). Warnings typically have to compete with other stimuli in the environment for attention. Several design factors influence how well warnings may compete for attention (see Wogalter and Leonard, 1999; Wogalter and Vigilante, 2006).

For visual presentation of information, larger is generally better. Increasing the overall size of the warning, its print size and contrast generally facilitate warning conspicuousness. Context also plays an important role. It is not just the absolute size of the warning but also its size relative to other displayed information that matters. Consider a workplace with multiple safety signs depicted in Figure 12.4. Here, the warning text for the signs *Hard Hat Required* and *Eye Protection Area* may be in direct competition with one another.

Colour is an important attribute that can facilitate attracting attention (Laughery et al., 1993b; Bzostek and Wogalter, 1999). While there are potential problems with using colour as the only method of conspicuousness, such as colour blindness in some individuals, colour is a frequently used design component to attract attention. Figure 12.5 is an example of the ANSI Z535 (2002) standard

FIGURE 12.4 Multiple warning signs in a workplace.

FIGURE 12.5 Illustration of the alert symbol in a signal word panel.

that uses colour (red in this example) as one of several components of the signal word panel to attract attention. Other design components in the ANSI Z535 signal word panel include an alert symbol, the triangle/exclamation point and one of three hazard connoting signal words (DANGER, WARNING and CAUTION). Context again can play a role with respect to colour as a salient feature. A red warning on a product label located on a red tool will have less salience than the same warning conveyed using a different colour. The colour should be distinctive in the environment where it is placed.

Symbols can also be useful for capturing attention. One example (depicted with the DANGER signal word panel in Figure 12.5) already mentioned is the alert symbol represented as a triangle enclosing an exclamation point (Laughery et al., 1993b; Bzostek and Wogalter, 1999). This symbol serves as a general alert. Bzostek and Wogalter (1999) found results showing people were faster in locating a warning when it was accompanied by an icon. Other kinds of symbols may be used to convey more specific information. This latter purpose is discussed in the later comprehension section, but the point here is that a graphic configuration can also benefit the attention switch stage.

Warnings located proximal to the hazard, both temporally and physically, generally increase the likelihood of attention switch (Frantz and Rhoades, 1993; Wogalter et al., 1995). Warnings should be located to maximise the chance that they will be encountered. This aids in delivery. For instance, a warning about carbon monoxide (CO) hazards on a gas-powered electrical generator is more likely to be effective than one located in a separate, sometimes displaced (e.g. in a file or possibly lost or never received), product manual (Wogalter et al., 1998c; Mehlenbacher et al., 2002). Generally, placement directly on the product or its primary container is preferred, particularly if the product is potentially highly dangerous (Wogalter et al., 1991, 1995). There may be exceptions to the proximity rule, such as where the warning is presented too close in location and/or time to the hazard, and the individual sees or hears it too late to avoid the hazard.

Repeated long-term exposure to a warning may result in a loss of its ability to evoke an attention switch at later times (Thorley et al., 2001; Kim and Wogalter, 2009). This process or state of habituation can eventually occur even with well-designed warnings; however, better designed warnings with salient features can slow the habituation process. As discussed in Wogalter and Mayhorn (2005), one of the benefits of technology-based warnings is that a warning's appearance can be changed to reinvigorate attention switch previously lost due to habituation.

Work-related tasks the individual may be performing and other stimuli in the environment may absorb attention and may compete with the warning for attention capture (Wogalter and Usher, 1999). While previous examples have focused on the visual modality, auditory perception is important as well. Consider the warehouse worker who is engaged in some task within a noisy environment where heavy equipment such as forklifts are in operation. Such a situation may present a safety hazard because auditory back-up alarms meant to alert workers to an approaching forklift must compete with other stimuli such as engine noise, talking co-workers or the presence of hearing protection devices that may detract from a worker's attention (Robinson and Casali, 1995). Thus, the warning should have characteristics to make it highly salient in context.

Attention Maintenance

Individuals may notice the presence of a warning but not stop to examine it. A warning that is noticed but fails to maintain attention long enough for its content to be understood may be of very little direct value. Attention must be maintained on the message for some length of time to extract meaning from the material. During this process, the information is encoded or assimilated with existing knowledge in memory.

With brief text or symbols, the warning message may be grasped very quickly, sometimes as fast as a glance. For longer more complex warnings, attention must be held for a longer duration to acquire the information. To maintain attention in these cases, the warning needs to have qualities that generate interest, so that the person is willing to maintain attention to it. The effort necessary to acquire the information should be as little as possible. Thus, a goal is to enable the information to be grasped as easily as possible. Some of the same design features that facilitate the switch of attention also help to maintain attention. For example, large print not only attracts attention but also tends to increase legibility which makes the print easier to read.

Print legibility can be affected by numerous factors including choice of font, stroke width, letter compression and distance between them, resolution and justification (see Frascara, 2006). Although there is not much research to support an unequivocal preference for particular fonts, the general recommendation is to use relatively plain familiar alphanumerics. It is sometimes suggested that sans serif font like Helvetica, Futura and Univers for large text sizes and a serif font like Times, Times Roman and New Century Schoolbook be used for smaller-sized text. A chart with print sizes for expected reading distances in good and degraded conditions can be found in the ANSI (2002) Z535.4 warning standard.

Legibility is also benefited by high contrast between objects, such as text lettering relative to their background. Consider the poor contrast between the warning text stamped into the orange metal background of the pneumatic nail gun illustrated in Figure 12.6. In this instance, it is unlikely that workers will notice let alone maintain their attention with this particular warning. Black on white or the reverse (as seen on the container of an industrial cleaner depicted in Figure 12.7) has the highest contrast, but legibility can be adequate with other combinations such as black print on yellow (as in the ANSI Z535.4 CAUTION signal word panel) and white print on red (as in the ANSI

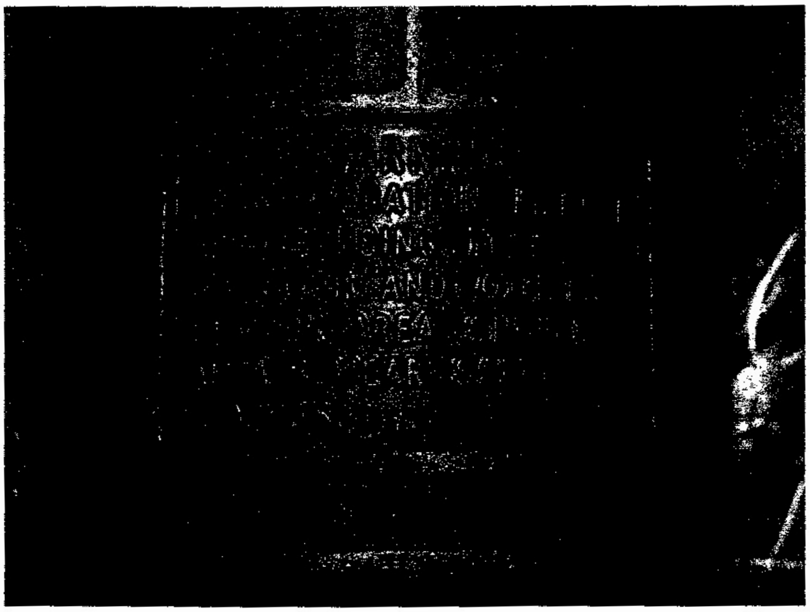

FIGURE 12.6 Embossed warning text in the metal of a nail gun.

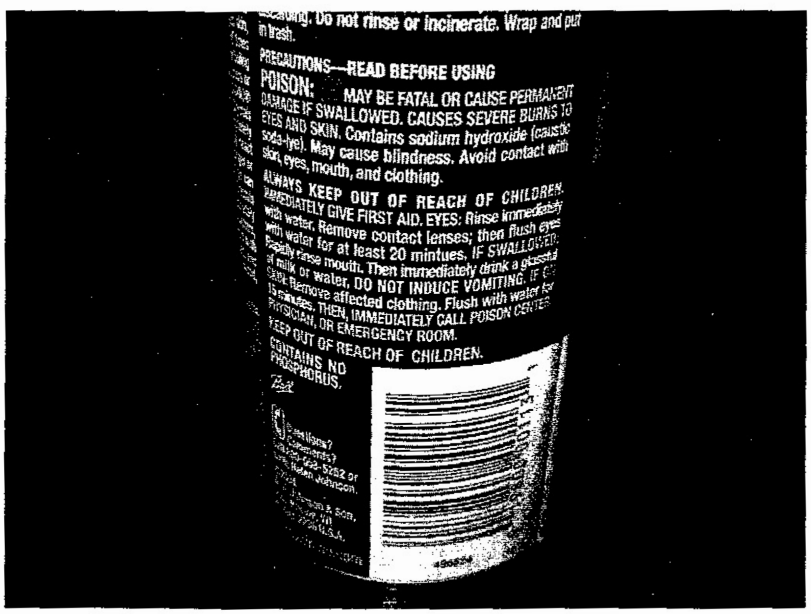

FIGURE 12.7 Text on a container of industrial cleaner.

Z535.4 DANGER signal word panel). In such a situation, the custodial workers interacting with the cleaning materials shown in Figure 12.7 are more likely to see and maintain attention on the safety information than the construction workers interacting with the nail gun and its illegible warning illustrated in Figure 12.6.

People will more likely maintain attention if a warning is well designed (i.e. aesthetic) with respect to formatting and layout. Research suggests that people prefer warnings that are in a list

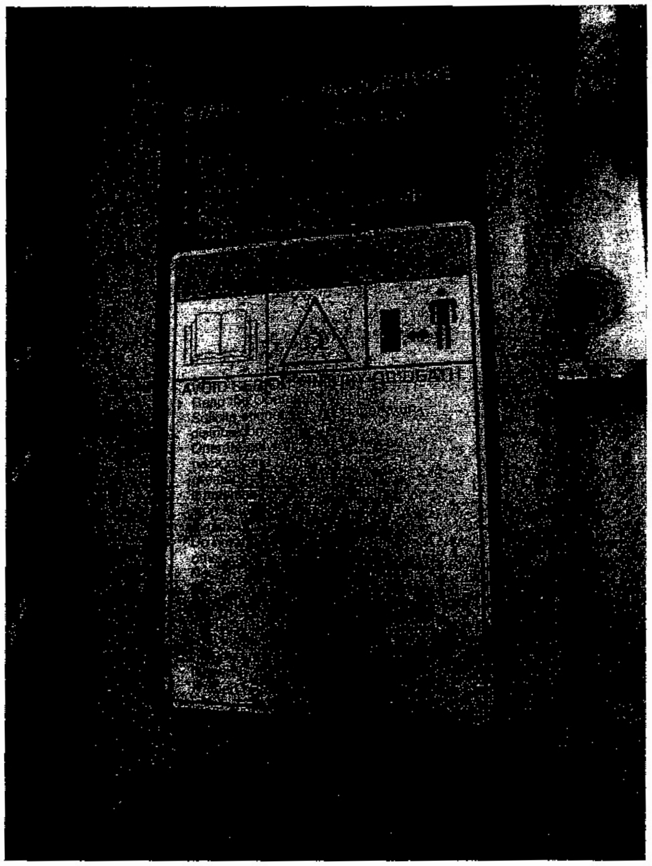

FIGURE 12.8 Warning label on a riding lawnmower.

outline format as opposed to continuous prose text (Desaulniers, 1987). Also, text messages presented in all capital letters are worse than mixed-case text in glance legibility studies (Poulton, 1967), and centred-line formatting is worse than left-justified text (Hooper and Hannafin, 1986). Because individuals may decide it is too much effort to read large amounts of text, structured formatting could be beneficial in lessening the mental load and perception of difficulty. Formatting can make the visual display aesthetically pleasing to help hold people's attention on the material. Formatting can help process the information by *chunking* it into smaller units. Such text alterations should specifically benefit working memory because this memory system is assumed to be directed by the central executive, an attentional controller (Baddeley et al., 2009). Formatting can also show the structure or organisation of the material, thus making it easier to search for and assimilate the information into existing knowledge and memory housed in long-term memory systems (Hartley, 1994; Shaver and Wogalter, 2003). Figure 12.8 illustrates an example of a well-formatted warning housed on a riding lawnmower where black, left-justified, mixed-case text is presented in the form of a bullet list on a white background.

Comprehension and Memory

Comprehension concerns understanding the meaning of something – in this case, the intended message of the warning. Comprehension may derive from several components: subjective understanding such as its hazard connotation, understanding of language and symbols, and an interplay with the individual's background knowledge. Background knowledge refers to relatively permanent long-term memory structure that may have resulted from exposure to safety information during on-the-job training, during organised safety meetings or from reading operator manuals for tools used in the workplace. The following sections contain short reviews of some major conceptual research areas with respect to warnings and the comprehension stage.

Signal Words

Aspects of a warning can convey a level of subjective hazard to the recipient. The ANSI (2002) Z535 standard recommends three signal words to denote different levels of hazard: DANGER, WARNING or CAUTION (see also Westinghouse Electric Corporation, 1981; FMC Corporation, 1985; Peckham, 2006). According to ANSI Z535, the DANGER panel should be used when serious injury or death *will* occur if the directive is not followed. A WARNING panel is used when serious injury or death *may* occur if the directive is not followed. The CAUTION panel is used when less severe personal injuries or property damage may occur if the directive is not followed. While the standard describes CAUTION and WARNING with different definitions, numerous empirical research studies indicate that people do not readily distinguish between the two. Although the term DEADLY has been shown in several research studies to connote significantly higher hazard than the standard's highest level DANGER, the use of DEADLY is not part of ANSI Z535 (see Wogalter and Silver, 1990, 1995; Wogalter et al., 1998a; Hellier and Edworthy, 2006).

Consider the lawnmower warning label illustrated in Figure 12.8 as an example of an ANSI-style signal word panel. According to ANSI Z535, the signal word panels for DANGER, WARNING and CAUTION are assigned specific colours: red, orange and yellow, respectively. This assignment provides a form of redundancy due to the presence of more than one cue. However, most people do not reliably distinguish different levels of hazard associated with the colours orange and yellow (Chapanis, 1994; Wogalter et al., 1998a; Mayhorn et al., 2004c), and so the effect of redundancy is probably not very beneficial in this case. The signal word panels also contain the alert symbol (triangle/exclamation point), which indicates it is a warning (Wogalter et al., 1994a, 1998a).

Message Content

The lawnmower warning illustrated in Figure 12.8 is an example of how a well-formatted industrial warning may fail due to inadequate warning content. Employees tasked with using a riding lawnmower must be made aware of *rollover* hazards where the operator might lose control when mowing on steep inclines. Rollover of the lawnmower onto the operator can result in potentially fatal crush injuries so it is imperative that operators understand the nature of the hazard from the warning. In general terms, the content of a warning message should include information about the hazard, instructions on how to avoid the hazard and the potential consequences if the hazard is not avoided (Wogalter et al., 1987). There are exceptions when the hazard is (1) general knowledge, (2) known from previous experience or (3) *open and obvious*, that is, apparent to everyone.

1. *Hazard information.* At a minimum, the warning should identify the safety problem. Oftentimes, however, warnings might require more information regarding the nature of the hazard and the mechanisms that produce it. In the case of Figure 12.9, the nature of the hazard is not described. Nowhere does the term *rollover* or *crush hazard* appear.
2. *Instructions.* Warnings should instruct people about what to do or not do. The instructions should be specific inasmuch as reasonable to tell what exactly should be done or avoided. The statement 'operate only on slopes you can back up and never on slopes greater than 15 degrees' does not tell that there is an injury potential due to rollover. In this case, without more information, operators are left making inferences which may be partly or wholly incorrect (Laughery et al., 1993a; Laughery and Paige-Smith, 2006).
3. *Consequences.* Consequences information concerns what could result. In Figure 12.9, *injury or death* is provided yet this statement is not sufficient to keep people from making incorrect inferences. As this warning illustrates, a common shortcoming in warning text

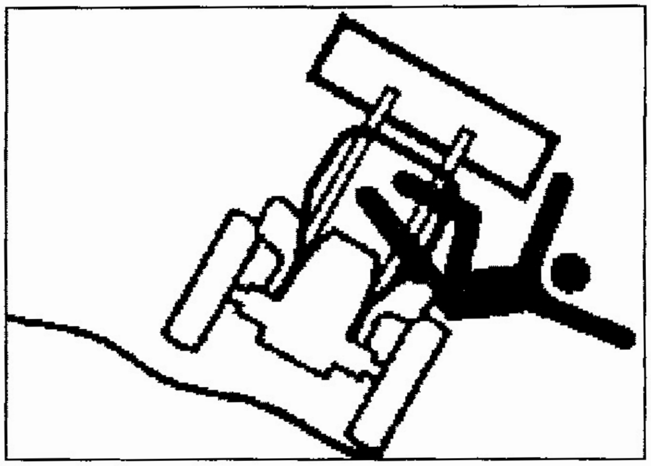

FIGURE 12.9 Rollover symbol that might supplement the warning label on a riding lawnmower.

is that consequences-related information is not explicit, that is, lacking important specific details (Laughery et al., 1993a; Laughery and Paige-Smith, 2006). For instance, consider the consequences statement 'Avoid serious injury or death' from Figure 12.9 in the context of the resultant crush hazard due to rollover. This statement is insufficient by itself as it does not tell what kind of injury could occur. The operator might believe contact with the components of the motor might result in a thermal burn rather than thinking that it could be something more severe, like a crush resulting in loss of a limb and perhaps death. In a later section, the specification of severe consequences is discussed as a factor in motivating compliance behaviour.

Symbols

Safety symbols such as the one depicted in Figure 12.9 may also be used to communicate the earlier-mentioned information regarding the rollover hazard in lieu of or in conjunction with text statements (e.g. Zwaga and Easterby, 1984; Young and Wogalter, 1990; Wolff and Wogalter, 1998; Dewar, 1999; Mayhorn et al., 2004b; Mayhorn and Goldsworthy, 2007, 2009). Not only might such a symbol act to tie the nature of the hazard to important instructions, but also the non-language attributes of symbols can contribute to understanding when illiterates or non-readers of the primary language are part of the target audience.

Comprehension is important for effective safety symbols (Dewar, 1999). Symbols that directly represent concepts are preferred because they are usually better comprehended than more abstract symbols (Wolff and Wogalter, 1993; Magurno et al., 1994; Wogalter et al., 2006). With abstract and arbitrary symbols (Sojourner and Wogalter, 1997, 1998; Wogalter et al., 1997; Lesch, 2003), the meaning typically has to be learned via training.

What is an acceptable level of comprehension for safety symbols? In general, symbols should be designed to have the highest level of comprehension attainable. The ANSI (2002) Z535 standard suggests a goal of at least 85% comprehension using a sample of 50 representative individuals from the target audience for a symbol to be used without accompanying text. If 85% cannot be achieved, the symbol may still have utility (e.g. for attention capture) as long as it is not likely to be misinterpreted. According to the ANSI (2002) Z535 standard, an acceptable symbol must produce less than 5% critical confusions (opposite meaning or a meaning that would produce unsafe behaviour). For example, a critical confusion might arise if lawnmower operators seeing the rollover symbol shown in Figure 12.9 misinterpret it to mean that sharp turns are acceptable as long as someone counterbalances the mower during operation. ISO (2001) has similar comprehension criteria (see Deppa, 2006; Peckham, 2006).

Repeated exposure to an unchanged warning over time will result in it being less effective not only in switching attention but also for maintaining attention (Kim and Wogalter, 2009). As mentioned earlier, even a well-designed warning will eventually become habituated if repeatedly encountered. Fortunately, habituation as a memory concept implies that the person has learned some amount of information from the warning to *know* to ignore it. Unfortunately, only part of the warning may actually be known. Some techniques for reducing habituation include (1) using salient features and (2) periodically varying the warning's appearance (and content, if feasible and appropriate).

Although individuals may have knowledge about a hazard, they may not be aware of it at the time they are at risk. Workers have vast stores of knowledge in long-term memory based on an accumulation of experience in their place of work. Despite this amazing memory storage space, at any given time, only a small portion of it is consciously available. As people are doing their work-related tasks, their minds are not always actively accessing risk information. Thus, while a person may have some or an extensive store of risk knowledge, this information and related knowledge may not be activated unless there is an external cue to activate it. Consider the potential threat to health-care workers from severe hypersensitivity to latex as might be encountered with latex gloves (Vredenburgh et al., 2006). Because they are focused on patient care and repeatedly exposed to warning information on boxes of latex gloves, health-care workers may experience habituation to a warning label where it is infrequently noticed. But its presence is better than its absence, as, for example, it may serve as a reminder to some persons susceptible to latex hypersensitivity. So despite habituation, the presence of a warning may serve to cue relevant hazard information.

In summary, information in long-term memory can be cued by the presence of a warning and bring forth related, previously dormant knowledge into conscious awareness. Reminders may be appropriate in situations (1) where the hazard is infrequently encountered in which forgetting may be an issue and (2) when there are foreseeable distractions or high task-load involvement (e.g. patient care) that could pull attention away from normative hazard considerations.

Level of Knowledge

The levels of knowledge and understanding of the warning recipients should be taken into consideration. Three cognitive characteristics of receivers are important: language skill, reading ability and technical knowledge.

With regard to the work environment, it is not unusual for workers to be given textual warnings beyond their reading skill. Consider the text from the cleaning product illustrated in Figure 12.8:

> PRECAUTIONS – READ BEFORE USING
>
> POISON: [skull & crossbones icon in red] MAY BE FATAL OR CAUSE PERMANENT DAMAGE IF SWALLOWED. CAUSES SEVERE BURNS TO EYES AND SKIN. Contains sodium hydroxide (caustic soda-lye). May cause blindness. Avoid contact with skin, eyes, mouth, and clothing.
>
> ALWAYS KEEP OUT OF REACH OF CHILDREN. IMMEDIATELY GIVE FIRST AID. EYES: Rinse immediately with water. Remove contact lenses; then flush eyes with water for at least 20 minutes. IF SWALLOWED: Rapidly rinse mouth. Then immediately drink a glassful of milk or water. Do not induce vomiting. IF ON SKIN: Remove affected clothing. Flush with water for 15 minutes. THEN, IMMEDIATELY CALL POISON CENTER, PHYSICIAN OR EMERGENCY ROOM.
>
> KEEP OUT OF REACH OF CHILDREN.

In general, reading levels should be as low as feasible. For the general population, the reading level probably should be approximately the skill level of grades 4–6 (expected ability of 10–12-year-old readers). In this instance, it is unlikely that the average worker will understand chemical references to sodium hydroxide and *caustic soda-lye*. When submitted to a readability analysis using the Flesch (1948) readability formula, the warning text given earlier was scored at a grade level of 6.3, which exceeds the skill level listed. Thus, the custodian tasked with using this product during the course of their work-related duties may be exposed to safety hazards because he or she did not understand the warning.

There are large numbers of functionally illiterate persons, even in some of the most technologically advanced countries. For example, in the United States, there are estimates of over 30 million functionally illiterate adults, and like everyone else, these individuals will likely have to work (Kutner et al., 2007). Thus, successful warning communication may require more than simply keeping reading levels to a minimum. The use of symbols, speech warnings and special training programs may be beneficial adjuncts. Also, a related consideration is that different subgroups within a population may speak and read different languages. Because of increasing international trade and travel and the need to cross language barriers, this problem might require the use of multiple languages, graphics and transmission through multiple methods (Lim and Wogalter, 2003). An example of a multilingual warning is illustrated in Figure 12.1, which depicts safety information on a heat gun used to remove wall paper and paint. It shows a pictorial of a fire and text in both English and French, and further on the right side is Spanish.

Despite considerations at the minimal end, reading levels should be consistent with the reading abilities and level of knowledge associated with the previous training of the receivers. Such variables are often dependent on the type of occupation. A warning to trained health-care professionals such as nurses, physicians and pharmacists should use standard verbiage expected by that population. These technical experts have a more complete understanding of domain-specific hazards and can perform their jobs better with area-appropriate technical data. In contrast, a tyre salesperson or professional installer of tyres cannot be expected to have extensive training on the hazards and warnings associated with tyre construction and how this might impact proper installation. Training on the topic is likely to be no more than a short course or two, and likely less, such as on the job training. Here the warnings might not be much different in the level of difficulty than those transmitted to the public. With regard to warning systems, different components of the warning system can be used to communicate to different groups.

Beliefs and Attitudes

Beliefs and attitudes is the next major stage of the C-HIP model. Beliefs refer to an individual's knowledge that is accepted as true (although some of it may not actually be true.) It is related to the previous stage in that beliefs are formed based on the examination of ideas stored in memory. In some respects, beliefs tend to be more global and overarching compared to specific memories. An attitude is similar to a belief except it includes more affect or emotional involvement.

A worker's benign experiences with a potentially hazardous tool can produce beliefs that a product is safer than it is. Consider the tree removal specialist who has operated the woodchipper without incident for years. A lackadaisical belief in equipment operation quickly changes after being involved in some way with (or seeing) a serious injury event. According to the C-HIP model, a warning will be successfully processed at the beliefs-and-attitudes stage if the message concurs (or at least is not discrepant) with the receiver's current beliefs and attitudes. However, if the warning information does not concur, then beliefs and attitudes may need to be altered before a person will be motivated to carry out the warning's directed behaviour. The message and/or other information need to be persuasive to override existing incorrect beliefs and attitudes. Methods of persuasion are commonly used in advertising and have been empirically explored in the social and cognitive psychology literatures. Recent applications of persuasion include the design and implementation of persuasive technology that includes the manipulation of computerised systems for the purpose of influencing attitudes and beliefs (Fogg, 2003). Sometimes not only unequivocal and explicit statements can be used to persuade but also the features of the warning may convey a higher-level importance. Such persuasion is important when a product is more hazardous than people believe. Discussed in the following paragraphs are several relevant and interrelated factors associated with the beliefs and attitudes stage: hazard perception, familiarity, prior experience and relevance (see DeJoy, 1999; Riley, 2006; Vredenburgh and Zackowitz, 2006).

Hazard perceptions influence processing at the beliefs-and-attitudes stage. The greater the perceived hazard, the more responsive people will be to warnings, as in looking for, reading and complying with them. The converse is also true. People are less likely to look for, read or comply with a warning for products that they do not believe are hazardous. Perceived hazard is closely tied to beliefs about injury severity. People perceive a product is more hazardous and act more cautiously when injuries could be severe (Wogalter et al., 1999). Interestingly, however, injury likelihood is a much less important factor in perceptions of risk or hazard for consumer products (Wogalter et al., 1991, 1993). Thus, the operator of the woodchipper will probably be swayed to comply with safety information if the extreme, though thankfully infrequent, consequence of losing a limb is communicated effectively.

Familiarity beliefs are formed from past similar experiences stored in memory. It is the belief that most everything that needs to be known about a product or situation is already known. A person believing that they are adequately familiar with a product might assume that a different, but similar, product operates in the same way and has the same hazards (which may not be true), reducing the likelihood that he or she will look for or read a warning (Godfrey and Laughery, 1984; Goldhaber and deTurck, 1988; Wogalter et al., 1991). For example, an employee familiar with one model of woodchipper may assume that a new piece of equipment possesses the same hydraulic feed system for capturing debris and delivering it to the cutting wheel. If, in fact, the feed system of the new equipment is much faster than that of the older device, employees may be at risk for having their limbs pulled into the device while loading debris due to this unexpected hazard and the mistaken belief that they are fast enough to avoid getting *sucked into the machine*.

Research indicates that hazard perception is more important than familiarity with respect to warnings (Wogalter et al., 1991). This is probably due to two factors. First, people more familiar with a situation or product may have more knowledge about the hazards and how to avoid them. Second, greater use also tends to increase exposure to warnings, which increases the opportunity to be influenced by them.

Related to familiarity is prior experience. The concepts are somewhat different in that familiarity is a belief (that may or may not be true), and prior experience is an objective quantity that could potentially be measured. Prior experience can be influential in hazard perceptions. Having experienced some form of injury or having personal knowledge of someone else being injured enhances the hazard perceptions (Wogalter et al., 1993). For instance, product users who were personally familiar with the hazards associated with cleaning solutions or who were aware of injuries to someone else were able to produce more effective hazard avoidance strategies (Mayhorn et al., 2004a). Similarly, the lack of such experiences may lead to underestimating dangers, or not thinking about them at all. Warnings that give vivid explicit consequences may convince people to change beliefs when they have inappropriate low levels of perceived hazard.

Perceived relevance is the belief that something is applicable to the person. If the individual does not believe the warning is relevant to them, then the warning may fail to fulfil its intended purpose. The individual may instead attribute the warning as being directed to others and not to him- or herself. For example, a truck driver transporting containers of pesticides to an agricultural community may mistakenly assume that warnings on the container are meant solely for farm workers. In such a case, the truck driver may erroneously believe that his limited exposure to the pesticide during the loading and offloading process is safe and that hand washing is not necessary. One way to counter this is to personalise the warning so that it gets directed to relevant users and conveys facts that indicate that it is relevant (Wogalter et al., 1994b).

A point related to beliefs and attitudes and more specifically, familiarity, concerns the problem of experts overestimating what people know, which in turn may affect what kinds of warnings are produced (Laughery, 1993). Experts in a domain can be so facile with their knowledge about a topic that they fail to realise that non-experts do not have similar knowledge. What is *obvious* to them may not be as equally obvious to end users. Without operator or end user input into the design of warnings, there may be a tendency to produce warnings that fail to meet the needs of workers.

Motivation

Motivation energises the individual to carry out an activity and serves as an essential component that links attitudes to actual behaviour as described in the theory of planned behaviour described by Ajzen (1991). Some of the main factors that can influence the motivation stage of the C-HIP model are cost of compliance, severity of injury, social influence and stress. These topics are discussed later in text.

Compliance generally requires that people take some action, and usually there are costs associated with doing so. The costs of complying may include time and effort to carry out the behaviour (Wogalter et al., 1987, 1989). When people perceive the costs of compliance to be too high, they are less likely to perform the safety behaviour. This problem is commonly encountered in warnings with instructions directing behaviours that are inconvenient, difficult, uncomfortable or occasionally impossible to carry out. For example, *long haul* truck drivers operate for extended periods of time that require them to use sleeper cabin berths inside their trucks (Darwent et al., 2012). To meet tight work deadlines, these drivers frequently operate in teams of two such that one can drive while his/her partner is sleeping. For safety purposes, a sleeper restraint system (e.g. seat belt for prone *off duty* driver in the berth) is provided. Unfortunately, death or injury due to ejection during a crash can occur. Anecdotally, many truck drivers have expressed an unwillingness to use the restraint system due to discomfort while sleeping. One way to reduce this cost of compliance is to make the directed behaviour easier and more comfortable to perform. Perhaps sleeper restraints that are designed using thicker padding might reduce discomfort and increase the likelihood of using this safety equipment. Such a finding would be consistent with previous research that indicates that the provision of protective devices such as gloves during tool operation reduces the costs of compliance (Wogalter et al., 1989; Dingus et al., 1991).

The costs of non-compliance can also exert a powerful influence on compliance motivation. With respect to warnings, the main cost for non-compliance is severe injury consequences. Previous research suggests that people report higher willingness to comply with warnings when they believe there is high probability for incurring a severe injury (e.g. Wogalter et al., 1991, 1993, 1999e). In this fashion, perhaps long haul truckers could be enticed to use their sleeper berth restraint systems if they are told it is similar to driving without a seat belt. Warning messages accompanied by explicit images depicting the fatal consequences of being ejected from a vehicle during a crash should be effective in further illustrating the costs of non-compliance.

Another motivator is social influence (Wogalter et al., 1989; Edworthy and Dale, 2000). When people see others comply with a warning, they are more likely to comply themselves. Likewise, seeing others not comply lessens the likelihood of compliance. Other factors affecting motivation are time stress (Wogalter et al., 1998b) and mental workload (Wogalter and Usher, 1999). Under high stress and workload, competing activities take resources away from processing warning information.

Behaviour

The last stage of the sequential process is for individuals to carry out the warning-directed safe behaviour. Behaviour is one of the most important measures of warning effectiveness (Silver and Braun, 1999; Kalsher and Williams, 2006). Warnings do not always change behaviour because of processing failures at earlier stages. Most research in this area focuses on the factors that affect compliance likelihood, including those that enhance safety behaviour and those that do not.

Some researchers have used *intentions to comply* as the method of measurement because it is usually quite difficult to conduct behavioural tests. The difficulties include the following: (1) researchers cannot expose participants to real risks because of ethical and safety concerns; (2) events that could lead to injury are relatively rare; (3) the stimulus scenario must appear to have a believable risk, yet at the same time must be safe; and (4) running such research is costly in terms of time and effort. Nevertheless, compliance is an important criterion for determining which factors work better than others to boost warning effectiveness and, consequently, safe behaviour in the workplace.

Virtual reality or simulation may play a role in allowing research to be conducted in simulated conditions that avoid some of the problems provided earlier (Duarte et al., 2010). Also compliance can be measured indirectly. For example, determining whether protective gloves have been worn can be gleaned from whether they appear to be used or stretched in appearance (Wogalter and Dingus, 1999; Kalsher and Williams, 2006). Likewise, sleep restraint system use in truck drivers could be assessed at a global level by determining whether the belt demonstrates wear and tear from use (as opposed to retaining the neatly folded, plastic wrapped factory configuration). (See Chapter 8 for further discussion of the role of simulation tools in E/HF research.)

Receiver Variables

The receiver's characteristics and task workload can affect warning effectiveness (Young et al., 1999). Indeed, evidence supporting this has already been discussed. Person variables (Rogers et al., 2000) such as the individuals' existing knowledge, beliefs and language skill were noted in earlier sections as affecting whether and how a warning is processed. Likewise, the demographic characteristics of workers should be considered. Previous research findings indicate that age-related declines in sensory and cognitive processing can affect warning processing particularly in attention switch and memory/comprehension stages (see Mayhorn and Podany, 2006; McLaughlin and Mayhorn, 2014). Because the world's workforce is ageing at an unprecedented rate, older employees may be placed at a heightened level of risk in certain occupations (Foster-Thompson and Mayhorn, 2012). For instance, older farmers have been shown to be differentially susceptible to tractor-related injuries due to decreased reaction time and other factors where age-related decrements have been observed (McLaughlin and Mayhorn, 2011). Thus, efforts to protect these particular workers would benefit from the development of age-appropriate warnings that take cognitive, motoric and perceptual abilities/limitations into account.

Given the increasing diversity of the workforce, other demographic factors also need to be considered. In some studies, gender differences have been noted (see, e.g., Laughery and Brelsford, 1991; Smith-Jackson, 2006a,b) with women being somewhat more likely to look for and read warnings (e.g. Godfrey et al., 1983; LaRue and Cohen, 1987; Young et al., 1989; Tam and Greenfield, 2010). Other research indicates that risk perception varies by ethnicity such that Latino farm workers reported higher risk perception associated with the use pesticides than Americans of European descent (Smith-Jackson et al., 2010).

Finally, warning processing occurs in the context of other potential processing given other stimuli in the environment and the individual's ongoing and ever-changing work behaviour. Whether and how a warning is processed can depend on mental workload (Wogalter and Usher, 1999), time stress (Wogalter et al., 1998b) and processing strategy (deTurck and Goldhaber, 1988). Consider one factory employee working under strict time constraints to meet a mandatory-specified quota versus an employee who is paid by the hour. The first individual operating under time pressure is probably not in an information-seeking mode and therefore is less likely to fully process a warning compared to the second individual who is not under those constraints. When such task loading can be anticipated (e.g. in emergency situations or when employees are working under time pressure), the warning system may have to be highly salient to attract attention.

A LOOK INTO THE FUTURE: TWENTY-FIRST-CENTURY INCLUSIVE WARNING SYSTEMS

To prepare for a future characterised by growing international trade and increased daily interaction between geographically separated co-workers, workplace warning systems currently in place must be adapted. To accommodate the needs of an increasingly diverse workforce as described earlier, inclusive warnings must be developed (Mayhorn et al., 2014). For instance, different cultural subgroups within the workforce of a single multinational corporation may speak and read different primary languages. Thus, an effective workplace warning must be able to cross cultural and language barriers.

One such attempt within the United States was assessed by Lim and Wogalter (2003), who concluded that culturally inclusive warnings require the use of multiple languages, combined graphics and transmission through multiple methods to reach various subpopulations that receive it.

As previously addressed, one potential solution to overcoming the language barrier might include increased reliance on pictorial symbols in warnings. Despite the apparent potential benefits to using symbols to convey hazard information, there have been a number of studies that show cultural differences in how people interpret the meaning of symbols. One example of such cultural differences was documented when ANSI symbols were tested for comprehension in Ghana. Severe interpretation discrepancies were noted for a number of symbols and their intended meanings (Smith-Jackson and Essuman-Johnson, 2002). Other research found that drivers from Canada, Israel, Finland and Poland displayed large comprehension differences among traffic signs (Shinar et al., 2003). Likewise, residents of Hong Kong had difficulty interpreting the meaning of some industrial signs used in Mainland China (Chan and Ng, 2010). Thus, symbols should be tested for comprehension within the intended target audience (even when the perceived subcultures are geographically proximal to one another) prior to deployment in a workplace warning system.

Just as the content of future warning systems might change, avenues for delivery of safety information are likely to change as well. With technology becoming ubiquitous in the workplace, safety professionals can begin to use the attributes of technology to create more effective dynamic warnings (Wogalter and Mayhorn, 2005). Not only could such use of technology combat information processing hurdles (i.e. habituation) to warning compliance identified in the content of the C-HIP model described earlier, dissemination could be tailored to meet the known characteristics of workers within a specific location. For instance, cellular telephone usage is commonplace, and many of these devices are equipped with global positioning systems. Because users enter their personal information (e.g. names and language preference) into these devices and carry them on their persons, an avenue for customised warning dissemination is now open where safety information can be delivered close in time and proximity to when it is needed. Such tailoring might also be used to impact the beliefs and attitudes of workers via persuasive technology (Fogg, 2003). Likewise, other technology such as computers and tablets are also available throughout the modern workplace for dissemination of warning information and training materials. As technology in the workplace continues to evolve, it is likely that warning systems will evolve to be more effective in promoting safe behaviour. Ultimately, the success of these future warning systems is dependent on how well safety professionals exploit these technological opportunities.

SUMMARY AND UTILITY OF THE C-HIP MODEL

The review of the warning literature as applied to the workplace environment was organised around the C-HIP model. This model is valuable in describing the information processing steps that occur when safety information is encountered and organising a large amount of previous research on the topic. Furthermore, it can also be a valuable tool in systematising the assessment process to help determine why a warning is not effective. It can aid in pinpointing where the bottlenecks in processing may be occurring and suggest solutions to allow processing to continue to subsequent stages. Moreover, workplace warning effectiveness testing can be performed using methods similar to those used in research settings. Evaluations of the processing can be directed to any of the stages described in the C-HIP model: source, channel, environment, delivery, attention, comprehension, attitudes and beliefs, motivation, behaviour and receiver variables. Some of the methods for doing this evaluation are briefly described here.

Evaluating the source necessitates an attempt to determine whether responsible parties such as employers and equipment manufacturers have documented the potential hazards and issued warnings. It is fundamental that workplace equipment manufacturers should analyse their products to determine whether there are foreseeable potential hazards associated with their use and misuse. When hazards are discovered, manufacturers have an obligation to employ methods to try to control the hazards to reduce personal injury and property damage. If a manufacturer is going to sell a product in which the hazard has not been eliminated through design or physical guarding, then it should provide effective warning(s) to end users such as employers forced to use these devices to earn a living.

Efforts to evaluate the channel of warning delivery mainly assess how safety information is sent to end users. What media and modalities are being used and are those adequate? Similarly, assessment regarding delivery asks whether end users receive the warnings. If not, other channels of distribution of warning materials may need to be considered. As mentioned earlier, the concept of *cascading responsibility* in the chain of commerce requires that the equipment manufacturers, intermediaries (e.g. distributors and retailers) and employers share a responsibility to provide workers with needed safety information (Williams et al., 2006). Thus, warning delivery must be assessed at each level of responsibility.

To assess attention switch, the main question is whether workers see or hear the warnings. The answer could involve placing a warning in the workplace and having people carry out a relevant task then asking them later whether they saw it (McGrath, 2011). Eye movement and response time paradigms represent other methods used to measure what people tend to look at and how quickly.

To assess comprehension, there are several well-established methodologies involving memory tests, open-ended response tests, structured interviews, etc. These assessment instruments can be valuable for determining what information was or was not understood and for suggesting revisions to warning text or symbols. To assess beliefs and attitudes, a questionnaire could be used to determine people's pre-existing beliefs on the topics of perceived hazard and familiarity with the tool, task or environment. For example, if workers' perceived hazard is too low for a situation, greater persuasiveness may be needed to promote warning compliance.

To assess motivation, measures of behavioural intentions can be used. Low intentions to comply may indicate that consequence information should be enhanced (e.g. by being more explicit) or that cost of compliance should be reduced. To assess behavioural compliance, systematic observation can be used in both lab and field settings. As mentioned earlier, measurement of behavioural compliance is generally more difficult than any of the other methods. It may involve ethical issues such as participants' exposure to risk. However, in situations where the negative consequences are substantial, the effort and resources may be warranted. Sometimes behavioural intentions are measured as a proxy for overt behavioural compliance – but, some caution should be exercised, as noted earlier.

In summary, workplace warning interaction can be conceptualised using the C-HIP model and investigated using the methods (and others) described earlier in a systematic manner. By determining the specific causes of a warning's failure, potential solutions can be generated and assessed. Resources can then be directed at fixing any shortcomings that limit observed warning effectiveness. In this manner, employers and employees can benefit from a safer, more productive workplace environment.

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