

## 20 Warning design

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*Information design:  
research and  
practice,  
pages 331–348*

Warnings are a type of risk communication intended to give people information about potential hazards and instructions to promote safe behaviour. Warnings can also serve as a reminder to cue access to existing knowledge. They serve as the third tier of hazard control with hazard elimination and guarding being the preferred methods. This chapter is organized around a Communication-Human Information Processing model that describes effective warning processing according to a set of stages involving a source, channel, and receiver. The receiver is further broken down into the stages of attention switch and maintenance, comprehension and memory, beliefs, motivation, and compliance. The influence of information design at each stage is discussed including format (size, contrast, colour, list/bulleting, graphics), content (chunking, graphics, signal words, and information on the nature of the hazard, consequences, and instructions), and context (aspects of product/environment, and awareness/knowledge). Methods for developing and evaluating warnings are given, including heuristic evaluation, iterative design, and testing of comprehension levels and response times.

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### **Definition and purposes of warnings**

Warnings are hazard communications, used in a variety of contexts to inform people about potential dangers and provide instructions to avoid or minimize undesirable consequences such as death, injury, or property damage. For example, a product warning for a wet-dry vacuum cleaner might inform people about an electrocution hazard; a sign warning might advise people to keep out of an electrical transformer box or other hazardous area.

Warnings reflect a fundamental right that people be given informed consent when placed into risky conditions. They also have another purpose. Consider that almost all adults know that lawnmowers have spinning blades that can cause severe injury but that sometimes this relevant information is not present in cognitive awareness when it is needed. In such cases warnings can bring to awareness latent knowledge (from long-term memory). Indeed the US Consumer Product Safety Commission (CPSC) requires a warning to be attached to all powered, walk-behind lawnmowers.

Since about the mid 1980s, research on the factors that influence the effectiveness of warnings, has resulting in a body of work that concludes that certain basic components can increase warning-sign effectiveness. These components are illustrated in this chapter, which focuses

cannot be completely eliminated by design, and sometimes guarding is incomplete. Sometimes called the strategy of 'last resort', warnings are third in the hazard control hierarchy. Returning to the blades of the power lawnmower: a cowl cover over the blades prevents most types of bodily contact; a so-called 'dead man's switch' stops the blades spinning if the operator releases the handle; the handle position distances the user from the blades and motor (guarding by distance). And yet, a warning is still needed to cover residual hazards after design and guarding have been employed. Given their important role in hazard control, warning design is of critical importance.

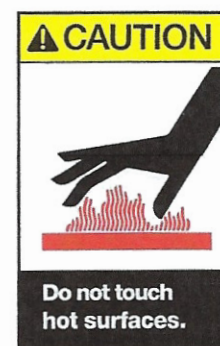
Figure 1 illustrates the ANSI Z535 warning sign, labels, and tags standard; 1a shows old-style panels and 1b the newer style. The ANSI signal words have different meanings in terms of hazard severity and probability:

- *danger*: a hazardous situation, which if not avoided, will result in death or serious injury (immediate and grave danger);
- *warning*: a hazardous situation, which if not avoided, could result in death or serious injury;
- *caution*: a hazardous situation, which if not avoided, could result in minor or moderate injury.

There is no signal word indicating that a minor injury will (definitely) occur. ISO (Organization for International Standardization) also suggests that warnings convey three levels of hazard (ISO 3864 2011).

'Danger' is printed in white with a red background, 'Warning' and 'Caution' are printed in black with an orange or yellow background, respectively. The Xs in Figure 1 indicate where text messages for particular warnings would be placed. The newer panels include the safety alert symbol (signal icon). Figure 2 shows an example ANSI Z535 warning, designed to inform people of the burn hazards associated with touching a hot surface.

**Figure 1**  
a. Old-style ANSI  
warning panel  
format.  
b. Newer style.



**Figure 2**  
Example ANSI warning  
panel for burn hazards.



## **Communication-Human Information Processing (C-HIP) model**

To help explain how people process warnings and how a warning might succeed or fail, the Communication-Human Information Processing (C-HIP) framework (see Figure 3) is useful (Wogalter, DeJoy, and Laughery 1999). C-HIP has two main parts:

- a basic communications framework to focus on a warning message being sent from a source (e.g. a manufacturer) to a receiver (e.g. an end-user) through some channel(s) (e.g. warning label, product manual)
- the stages of information processing, from attention switch and maintenance, through memory/comprehension, beliefs/attitudes, to motivation and compliance. Linear processing through these stages is implied, with inability to process information in an earlier stage preventing or limiting later processing. Nonlinear processing, where later stages affect processing in earlier stages, is illustrated by feedback loops.

We use the C-HIP framework in the following sections to discuss information design factors in warnings, covering first the communication features of C-HIP and, subsequently, factors in the receiver's internal information processing.

### **Source**

The source (e.g. a manufacturer with responsibility for warning) is the initial transmitter of the warning information. The source must determine if there are hazards present that necessitate a warning through some form of hazard analysis (e.g. Young, Frantz, and Rhoades 2006) and should consider, first, if there are better ways of controlling hazards, as discussed above, by eliminating or guarding against them.

### **Channel**

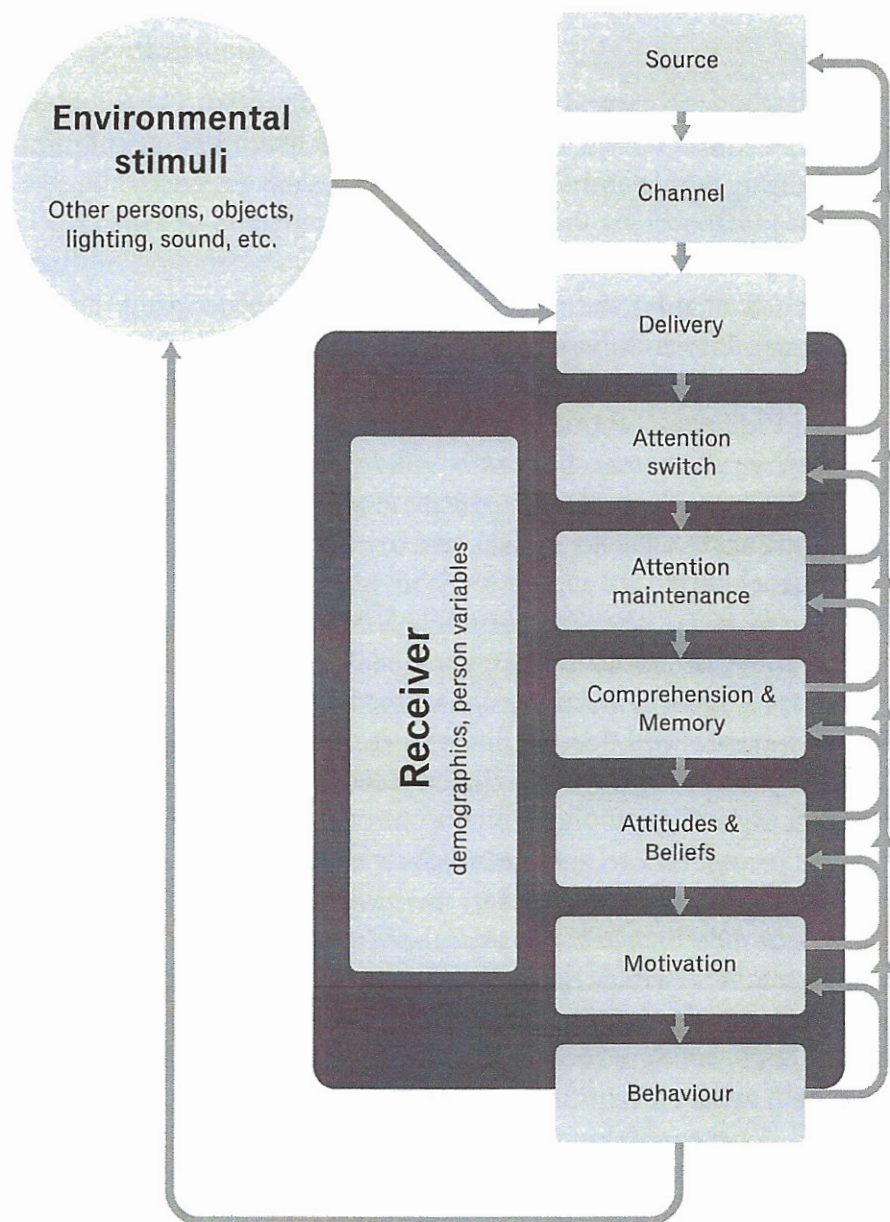
The channel is the medium where the information is embedded (e.g. label, video) and modality (visual, auditory) that transmits information from the source to receivers. Some media involve one modality (e.g. product manual involves the visual sense) and others involve two (e.g. videos often have both visual and auditory components). Visual presentation can be in the form of text and/or graphics, such as symbols. Multimodal warnings are more effective than single modality warnings because they provide redundancy (e.g. Baldwin et al. 2012b).

### **Delivery**

Delivery refers to the point of reception where a warning arrives at the receiver. A warning that a person sees is a warning that has been delivered.



**Figure 3**  
Communication-  
Human  
Information  
Processing (C-HIP)  
model.  
(After Wogalter 2006b).



However, warnings might not reach some of the targets at risk (Williamson 2006). A warning in a manufacturer's brochure that hardly ever reaches the end-user is ineffective; for example, the brochures may be in a warehouse, undistributed due to cost cutbacks. Because warnings may miss being delivered to individuals, manufacturers need to consider using multiple channels to increase the likelihood that they will reach end-users.

### Environmental stimuli

Other stimuli are almost always simultaneously present with warnings. These may be other warnings and a wide assortment of non-warning stimuli. They compete for attention and could interfere with warning processing. Interference is more likely if the other stimuli in the environment are highly salient (conspicuous or prominent).



### Receiver

The receiver is the person to whom the warning is directed. The following sections describe how, once a warning has been delivered, stages of information processing within the receiver influence its effectiveness.

### Attention switch

Attention switch enables the first stage of warning processing. Several design factors influence how well warnings may compete for attention with other stimuli in the environment (Wogalter and Leonard 1999; Wogalter and Vigilante 2006).

Larger is generally better. Increasing the overall size of a warning, its type size and contrast increases its conspicuity. It is not just the absolute size of the warning, but also its size relative to other information in its context that matters.

Colour can facilitate attention switching (Bzostek and Wogalter 1999; Laughery et al. 1993b). As seen in Figures 1 and 2, ANSI Z535 uses colour, as one of several components of the signal word panel, to attract attention. Its salience, however, will depend on context. A red warning on a mostly red-coloured product will have reduced salience. Thus distinctiveness aids attention capture.

Graphical configurations such as symbols and icons can also elicit an attention switch. The alert symbol in the newer ANSI Z535 signal word panels is an example. Bzostek and Wogalter (1999) found people located warnings on medicine labels more quickly when they were accompanied by symbols (e.g. an alert symbol, skull and crossbones, etc.).

The ANSI Z535 configuration of signal word panel has several features that could help attract attention (relatively large type size, colour, and an alert symbol). A potential downside of consistently using a recommended configuration is that, with repeated exposure, habituation could negatively affect attention (Kim and Wogalter 2009; Thorley, Hellier, and Edworthy 2001). However, features such as distinctive shapes and colour may slow the habituation process. Note that in the former Z535 style each signal word panel had a distinctive shape/configuration, which disappeared in the newer set of panels (see Figure 1).

Warnings should be located near the hazard, both temporally and physically to maximize the chance that they will be encountered (Frantz and Rhoades 1993; Wogalter, Barlow, and Murphy 1995). Placing a warning directly on the product or its primary container is preferred. Product manuals and information sheets are often discarded, lost, or if pre-owned, never received (Mehlenbacher, Wogalter, and Laughery 2002; Wogalter, Vigilante, and Baneth 1998). There are exceptions, however, where a warning is too close in location or time to the hazard, and the individual sees it too late; or where other tasks the individual is performing may compete with the warning for attention (Wogalter and Usher 1999).



### Attention maintenance

Individuals may notice the presence of a warning but still not stop to examine it. Attention must be maintained on the information for it to be assimilated with existing knowledge in memory.

In order to quickly and easily communicate important warning information, content should be as brief as possible. Warnings need to have qualities that make them easy to grasp and avoid aspects that slow down or cause the reader to stop processing them. Some of the same design features that facilitate attention switch, discussed above, also help maintain attention (Wogalter et al. 1999a). For example, large print attracts attention and, by increasing legibility, makes content easier to read.

Print legibility can be affected by numerous factors including choice of font, stroke width, letter compression, etc. (Frascara 2006). Research does not support an unequivocal preference for particular fonts, although the general recommendation is for relatively plain, familiar alphanumeric lettering, presented in mixed case rather than all capitals. ANSI Z535.4 includes a chart with print sizes for expected reading distances for both good and degraded lighting. Legibility is also improved by high contrast of the text relative to its background. Over time, and with wear-and-tear of environmental exposure and ageing, legibility is likely to be reduced.

Formatting warning content by 'chunking' it into distinct categories can assist in information acquisition, making the information easier to search and remember (Shaver and Wogalter 2003). Structured formatting reduces perceived difficulty and mental workload (Desaulniers 1987; Mendat et al. 2005). Figure 4 shows an over-the-counter pharmaceutical product label displaying the 'Drug Facts' format required by US law. Evidence suggests

<b>Drug Facts</b>	
<b>Active ingredient</b> Isopropyl alcohol 70%.....	<b>Purpose</b> First aid antiseptic
<b>Use</b> First aid to help prevent the risk of infection in: • minor cuts • scrapes • burns	
<b>Warnings</b> For external use only	
<b>Flammable</b> • Keep away from fire or flame	
<b>Ask a doctor before use if you have</b> deep or puncture wounds, animal bites or serious burns	
<b>When using this product</b> • do not get into eyes • do not apply over large areas of the body • do not use longer than 1 week unless directed by a doctor	
<b>Stop use and ask a doctor</b> if condition persists or gets worse	
<b>Keep out of reach of children.</b> If swallowed, get medical help or contact a Poison Control Center right away.	
<b>Directions</b> • clean the affected area • apply a small amount of this product on the area 1 to 3 times daily • may be covered with a sterile bandage • if bandaged, let dry first	
<b>Other information</b> • does not contain, nor is intended as a substitute for grain or ethyl alcohol • will produce serious gastric disturbances if taken internally	
<b>Inactive ingredient</b> water	

**Figure 4**

Over-the-counter pharmaceutical product label displaying the 'Drug Facts' format required by US law.



that consumers extract information quicker from standardized labels than from labels that do not follow such formatting (Kalsher, Wogalter, and Racicot 1996; Wogalter, Shaver, and Chan 2002).

The formatting guidelines of the ANSI Z535 reflect some research findings but not all of them. Warning designers need to know the applicable standards in their country. And where there are not answers, research literature provides a resource that goes beyond standards.

### Comprehension and memory

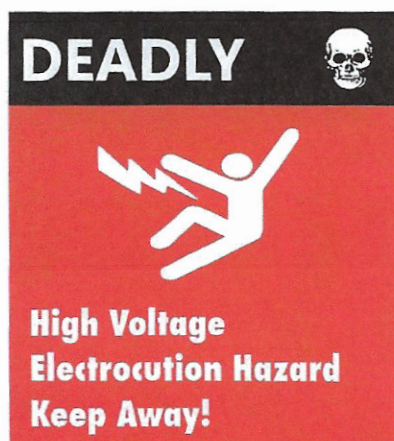
Warning comprehension may derive from:

- subjective understanding, such as the hazard connotation of a signal word or colour;
- understanding the text;
- understanding graphical features, such as symbols;
- an individual's background knowledge and beliefs; that is, long-term memory formed from prior exposures to the information.

The subsections below review some major warning features pertinent to the comprehension stage.

### Signal words

As described earlier, ANSI Z535, and other standards, designate three specifically defined signal words (Danger, Warning, and Caution) to denote levels of hazard probability and severity. While Caution and Warning have different definitions, empirical studies indicate that people do not readily distinguish between the two. Danger connotes a more significant injury than either Warning or Caution. The term Deadly is not part of ANSI Z535 but several studies have shown that it connotes significantly higher levels of hazard than the three standard signal words (Hellier and Edworthy 2006; Wogalter et al. 1998a; Wogalter and Silver 1990, 1995). Figure 5 shows use of the signal word Deadly to warn of an electrocution hazard.



**Figure 5**

Exemplar warning panel using the signal word DEADLY.

**Figure 6**

Two product warning labels concerning spontaneous combustion hazard.

a. Label found on wood stain cans in the USA.

b. Another version that conveys how to discard the product in a somewhat clearer manner.



### Colour

As discussed earlier ANSI Z535 assigns specific colours, red, orange, and yellow, for Danger, Warning, and Caution respectively. As with signal words, people rate red as higher hazard than the other colours, but do not reliably distinguish the hazard associated with orange and yellow (Chapanis 1994; Mayhorn, Wogalter, and Shaver 2004; Wogalter et al. 1998a; Wogalter, Mayhorn, and Zielinska 2016).

### Message content

The content of a warning message should include three main components: information about the hazard, instructions on how to avoid it, and the potential consequences if instructions are not followed (Wogalter et al. 1987). Additional information may be required beyond these general categories.

Specific descriptions are more likely to encourage users to act cautiously than general information (Laughery and Paige-Smith 2006; Laughery et al. 1993a).

Consider the two warnings from containers of wood stain products in Figure 6. Both warn about the potential for rags used during product application to catch fire spontaneously if disposed of incorrectly. While 6a is commonly used in the USA, 6b is a revision that describes safe disposal more clearly (for example, that the water filled metal container is not just for 'temporary storage').

**Figure 6**  
Two product warning labels concerning spontaneous combustion hazard.  
a. Label commonly found on wood stain cans in the USA.  
b. Another version that conveys how to discard the product in a somewhat clearer manner.

**To avoid spontaneous combustion during temporary storage, soak soiled rags and waste immediately after use in a water-filled, closed metal container.**

a

**DANGER:** Rags, steel wool, other waste soaked with this product, and sanding residue may spontaneously catch fire if improperly discarded. Immediately place rags, steel wool, other waste soaked with this product, and sanding residue in a sealed, water-filled, metal container. Dispose of in accordance with local fire regulations.

b

### Symbols

Safety symbols can provide information, either in lieu of or together with textual statements (e.g. Dewar 1999; Mayhorn and Goldsworthy 2007, 2009; Mayhorn, Wogalter, and Bell 2004; Wolff and Wogalter 1998; Young and Wogalter 1990; Zwaga and Easterby 1984). Symbols can sometimes have value as a means to communicate to people who do not understand the textual components.

Symbols that directly represent concepts are usually better understood than more abstract symbols. Figure 7 (overleaf) is a well-designed pictorial warning communicating electrical hazard and possible consequences of



**Figure 7**

Electrocution hazard sign (based on an original from Puerto Rico) with symbols and Spanish text.

flying a kite near high voltage wires. The relationship between the hazard and consequences can be understood without being able to read the text. However, symbols are difficult to design for concepts that are invisible (such as radiation), have a time course, or represent an abstract or complex concept (Wogalter et al. 2006). Typically, the meaning of abstract and arbitrary symbols has to be learned (Lesch 2003; Wogalter, Sojourner, and Brelsford 1997).

Symbols should be designed to have the highest level of comprehension attainable. For a symbol that will be used without accompanying text ANSI Z535 suggests a goal of at least 85% comprehension using a sample of 50 participants representative of the target audience. Additional cultural differences affect symbol interpretation. Tests of conventional ANSI symbols in Ghana revealed severe interpretation discrepancies from the intended meaning (Smith-Jackson and Essuman-Johnson 2002). Other research found comprehension differences for traffic signs across Canada, Israel, Finland, and Poland (Shinar et al. 2003). Likewise, Hong Kong residents had difficulty interpreting some industrial signs used in mainland China (Chan and Ng 2010). If 85% comprehension cannot be achieved, the symbol may still have utility by aiding attention switch and helping at least some people understand the message. Some kinds of interpretation errors are worse than others, particularly misinterpretations that could increase the potential for injury. According to ANSI Z535, an acceptable symbol must produce fewer than 5% critical confusions (opposite or wrong answers that might lead to unsafe behaviour) using a sample of 50 participants.



*Reminder value*

Although people hold knowledge about hazards in long-term memory, at any given time only a small portion of that knowledge is consciously available. As people are doing tasks, attention to safety-related information may need to be cued by a warning. Reminder warnings may be appropriate in situations where a hazard is infrequently encountered so that memory degrades over time, or where foreseeable distractions or high mental workload could distract attention from hazard considerations.

*Level of knowledge*

The message receiver's knowledge should be considered, particularly their language skill and technical knowledge. Open-ended comprehension tests can be used to assess whether people understand the hazard and the consequences and instructions statements. Where there is a need to cross language barriers, multiple languages, graphics, and transmission through multiple methods and channels may be needed (Lim and Wogalter 2003; Mayhorn et al. 2014).

**Attitudes and beliefs**

Beliefs refer to an individual's knowledge base that they accept as true (although some of it may not actually be true). Attitudes are similar to beliefs but include the involvement of emotion.

According to the C-HIP model, a warning will be successfully processed if its message concurs (or at least is not discrepant) with the receiver's beliefs and attitudes. If warning information does not concur with existing beliefs and attitudes, it may need to be persuasive so as to override them. Persuasion is particularly important when a product is more hazardous than people believe, possibly as the result of a build up of benign experiences and memories associated with it. For example, an individual may have used over-the-counter pain relief containing paracetamol/acetaminophen with no adverse effects, which may reduce their receptivity to new warning messages. Incorrect beliefs about safety can also come from advertising campaigns that convey a product's positive benefits without giving any negatives.

The greater the perceived hazard, the more responsive people will be to warnings. Perceived hazard and willingness to act with caution are closely tied to beliefs about injury severity (Wogalter et al. 1999b), whereas injury likelihood appears to be less important in people's judgements (Wogalter et al. 1991; Wogalter, Brems, and Martin 1993). An individual's belief that they are familiar with a product will reduce the likelihood of them looking for or reading a warning (Godfrey and Laughery 1984; Goldhaber and deTurck 1988; Wogalter et al. 1991).

Hazard perception can be enhanced by prior experience of injury or personal knowledge of someone else being injured (Mayhorn et al. 2004). Lack of such experiences may lead people to fail to consider or to



underestimate dangers. Warnings that give explicit consequences may provide some of the persuasion needed to change beliefs when perceived hazard is inappropriately low.

For a warning to succeed, the recipient must believe it is relevant. Individuals may instead believe a warning is directed to other people, rather than to them. Such beliefs may be overcome by personalizing warnings, directing them to specific users and conveying facts that are relevant to them (Wogalter et al. 1994). Available technology may enable tailoring warnings to the characteristics of people within a specific location; for example, using their personal information (names, language preference, etc.) entered into mobile phones or other devices (Wogalter and Mayhorn 2005).

Experts in a domain can be so facile with their knowledge about a topic that they overestimate what people know, which in turn may affect what kinds of warnings are produced (Laughery 1993). Without operator or end-user input into the design, the warnings produced may be poor.

### **Motivation**

Motivation energizes the individual to carry out an activity, linking beliefs and attitudes to actual behaviour, but it is susceptible to several influencing factors.

Compliance with warnings generally requires time and effort (Wogalter et al. 1987; Wogalter, Allison, and McKenna 1989). When people perceive the costs of compliance to be too high, they are less likely to perform safety behaviours. Perceived cost of compliance can sometimes be reduced; for example, the cost of using protective gloves can be reduced by including gloves with the product (Dingus, Hathaway, and Hunn 1991; Wogalter, Allison, and McKenna 1989). Additionally, people report higher willingness to comply with warnings when they believe there is high probability for incurring a severe injury (Wogalter, Brems, and Martin 1993; Wogalter et al. 1991, 1999b). Warnings including explicit wording and images depicting severe consequences may help motivate compliance.

The social influence of seeing others comply with a warning can also motivate compliance (Wogalter, Allison, and McKenna 1989; Edworthy and Dale 2000). The reverse is also true. Other influential factors are time stress (Wogalter et al. 1998b) and mental workload (Wogalter and Usher 1999) where competing activities can detract from processing warnings, reducing the likelihood of compliance.

### **Behaviour**

Behavioural compliance is one of the most important measures of warning effectiveness (Kalsher and Williams 2006; Silver and Braun 1999) but is usually difficult to test since:

- researchers cannot expose participants to real risks because of ethical and safety concerns;



- events that could lead to injury are relatively rare;
- the stimulus scenario must appear to have a believable risk, yet at the same time must be safe;
- running such research is costly in terms of time and effort.

Compliance can sometimes be measured indirectly; for example, determining whether protective gloves have been worn from the appearance of stretch marks (Wogalter and Dingus 1999; Kalsher and Williams 2006). Virtual reality or simulation may allow research that avoids some of the difficulties discussed above (Duarte, Rebelo, and Wogalter 2010). Because of the difficulty in measuring actual behaviour, many researchers use a ratings-type measure of 'intentions to comply', comprised of subjective judgements.

### **Assessing the effectiveness of warnings**

One of the main methods of assessing warnings is through a checklist of characteristics or features that have been found useful in research. Wogalter (2006a) give such a list. Warnings can also be assessed through heuristic evaluation, similar to a checklist evaluation except that an expert in warnings does it.

An alternative approach is to test warnings using participants. Although focus groups can be used and are sometimes beneficial in collecting ideas, they have limitations, such as the group being influenced by one or two individual participants. A better method is to conduct iterative cycles of design and test across several rounds of participants, tested individually, who are asked various questions about the warnings. Information gathered at each round is used to aid redesigning and fixing the warning. The revised warning is then shown to another set of individuals who again give feedback, the process continuing until the warning appears satisfactory. However, even at this point the process is not complete until a larger pool of participants is tested to assure the resulting warnings communicate their intended message effectively.

Warning salience in context can be determined by asking test participants to rate on a numbered scale how well a warning attracts their attention when features (colour, presence of symbols, etc.) are manipulated (Zielinska, Wogalter, and Mayhorn 2014). Measuring reaction time or speed of responses provides a more objective measure (Bzostek and Wogalter 1999), as can studying eye movement to assess where people make initial glances and eye movements to various parts of visual materials (Laughery et al. 1993b). More on evaluation methodologies can be found in Wogalter, Conzola, and Vigilante (2006). Note that once a warning is put into use on a product, it should be reviewed over time to see if it can be improved, particularly if critical events such as reported injuries continue.



### C-HIP model as an investigative tool

This C-HIP model can be used as tool to systematize the assessment of a warning that is not effective, to help pinpoint bottlenecks in processing and suggest solutions that allow processing to continue.

Evaluation can be directed to any stage in the model. Evaluating the source perhaps differs a little from other stages. It is fundamental that manufacturers analyse their products to determine and document residual hazards that could result in injury. When hazards become known, manufacturers have an obligation to try to control them. One way is to use effective warnings.

Warning channel mainly concerns how safety information is sent to end-users. If the assessment suggests end-users are not receiving warnings then the distribution channels may need to be reconsidered. The concept of 'cascading responsibility' in commerce requires that equipment manufacturers, intermediaries (e.g. distributors and retailers) and employers share a responsibility to ensure that users are provided with needed safety information (Williams, Kalsher, and Laughery 2006).

The success of attention switch can be measured by placing a warning in expected environments or locations where people carry out a relevant task and then asking them later whether they saw it (McGrath 2011). As discussed above, head and eye movement tracking and response time recordings may be used to determine a warning's effectiveness in context.

Comprehension may be assessed by memory tests, open-ended response tests, structured interviews, etc. People's pre-existing beliefs and attitudes regarding perceived hazard and their familiarity with the tool, task, or environment may be determined through questionnaires so that if, for example, perception of hazard is too low, greater persuasiveness can be applied.

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. Behavioural intentions are not the same as actual behavioural compliance, so some caution should be exercised. While measuring behavioural compliance is difficult, when the negative consequences of an ineffective warning are substantial, the effort and resources may be warranted.

Why should such high level of care be taken to design and present warning information? The answer has been given throughout this chapter. Warnings are needed when product designers or employers or public communities cannot (or for other reasons do not) design out or guard against all of the hazards. Warnings should be constructed to be effective to fulfil their role in hazard control. There are plenty of tools in the toolbox for the warning designer to accomplish an effective design.

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# Information design research and practice

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# Information design

research and practice

edited by

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First published 2017  
by Routledge  
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge  
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

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British Library Cataloguing in Publication Data  
A catalogue record for this book is available from the British Library

Library of Congress Cataloging in Publication Data  
CIP data has been applied for

ISBN: 978-0-415-78632-4 (pbk)  
ISBN: 978-1-315-58568-0 (ebk)

*Publisher's Note*

This book has been prepared from camera-ready copy provided by the editors.  
Typeset in Adobe Text, Monotype Classic Grotesque, and TypeTogether Abril families  
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