CHAPTER SEVEN

# Attention Capture and Maintenance

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This chapter describes the processes involved in attention to warnings. Attention has two stages. One is the capture or switch stage in which the warning must capture attention by standing out from other stimuli in cluttered and noisy environments. Attention is more likely to be drawn to a warning if it has features that enhance its conspicuousness. The second stage, maintenance, holds attention while and until information from the warning is extracted. Features such as legibility and intelligibility are involved. Recommendations for research and application are presented.

*Note: Figures that do not appear in the text of this chapter are shown in the color plate section.*

## 7.1 INTRODUCTION

Most environments are cluttered and noisy, and frequently people's attention is divided among various stimuli. According to most modern theories of attention, people have limited pools of mental resources that are used for attending and for working (conscious) memory (e.g., Baddeley, 1986). In other words, we cannot simultaneously attend to everything around us, as it would exceed the available attention capacity. Nevertheless, we can do several tasks simultaneously if they are highly practiced, automatic procedures that consume a fraction of the available capacity. Less practiced tasks are more effortful, consume more resources, and tend to require more serial, one-at-a-time, processing that can exceed capacity and degrade performance if performed concurrently with another task.

In general, we tend to look at, listen to, or think about the most salient features of our external environment or internal thought processes. As we attend to the most salient stimuli, memories of that information are produced. As memory is formed, the stimulus becomes relatively less salient, and other stimuli or thoughts become relatively more salient. Thus, as salience diminishes for one stimulus, attention may switch to a more salient stimulus. In other words, there is an on-going, continuous process of holding and switching attention to the most salient current stimulus or thought.

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As the above description suggests, there are two stages of attention. One is the capture or switch stage in which a good warning serves as an attractor that draws or captures attention away from other stimuli or thoughts. To capture attention, the warning needs to be more salient than other events in the environment or those being internally processed. The second stage of attention is maintenance. Here, attentional focus is retained on the warning message while information is extracted and memory is formed (e.g., while a person examines the stimulus material). To expedite information extraction, a visual warning needs to be easy to read and legible. Likewise, an auditory warning must be easy to listen to and intelligible. In this chapter, we will focus on factors that affect both capturing and maintaining attention to visual and auditory warnings.

### 7.1.1 Modalities

Most warnings are transmitted visually (e.g., signs and labels) or auditorily (e.g., tones and speech). These two sensory channels or modalities are the most frequently studied in research and used in applications and, as a consequence, they are the primary foci of this chapter. Vision and audition have somewhat different characteristics (e.g., different temporal and spatial attributes), and because of these differences, certain warning features that are effective for one sensory channel are not appropriate for the other channel and vice versa. Compared to visual warnings, relatively less research has been performed on the factors that influence attention capture and maintenance of auditory warnings. However, research in this domain is increasing rapidly (see Stanton, 1994; Edworthy, Stanton, and Hellier, 1995; Edworthy and Adams, 1996).

Hazard information can be transmitted also through other sensory modalities. Examples include the olfactory sense (e.g., the odor added to natural gas to aid detection of leaks), the gustatory sense (e.g., an extremely bitter taste added to some household cleaning products), and the kinesthetic/tactile senses (e.g., a 'stick-shaker' that vibrates aircraft control sticks to warn pilots of an impending stall). These examples show that these 'other' sensory modalities may be quite useful in communicating hazard information, and probably should be used more frequently when applicable and practical. Example situations include (a) communicating to individuals who have limited visual and auditory capabilities, and (b) providing an extra, redundant cue when other cues might be missed or not easily given. We return to the issues associated with sensory capabilities and multiple cues at a later point in this chapter.

The next section reviews factors that can influence attention capture and maintenance. An immense amount of research has been conducted on factors that influence attention. Consequently, we have had to be somewhat selective in the breadth and depth of the material covered. We refer readers to the cited references for further details.

## 7.2 ATTENTION CAPTURE

To attract attention while other stimuli are being processed, warnings must be adequately conspicuous relative to the particular background context in which they occur (Wogalter *et al.*, 1987; Young and Wogalter, 1990; Sanders and McCormick, 1993). Warnings must possess characteristics that make them prominent and salient so that they stand out from background clutter and noise (Frantz and Miller, 1993; Wogalter, Kalsher, and Racicot. 1993a).

In the sections that follow we describe factors that influence attention capture to warnings. We first describe the effects relevant to visual warnings followed by those relevant to auditory warnings.

### 7.2.1 Vision

Visual warnings are provided in a variety of media including printed labels, posters, signs, brochures, inserts, and product manuals. Some types of visual warnings are presented electronically in the form of simple on/off lights, gauges, video displays, etc. Perceptual enhancements that increase the noticeability of warnings can facilitate attention capture, whereas deficiencies in these characteristics can cause a failure to attract attention. The following sections describe some factors that influence attention capture.

#### *Environmental conditions*

Environmental conditions can adversely impact warning detection. One common problem is low illumination. Insufficient light makes printed warnings less visible. Warning visibility can be aided by adding an artificial light source directed at the surface or by back lighting it. Another strategy is to make maximum use of the light that exists, by using, for example, a retroreflective surface coating.

Too much light also can impair visibility. Glare occurs when large amounts of light reflect off a warning surface into the eyes, overpowering the print. Glare can be caused also by intense light emanating directly from a nonwarning source, such as oncoming headlights (cf. Dahlstedt and Svenson, 1977), or certain kinds of neon sign and strobe light. Wogalter *et al.* (1993a) noted that a warning sign with an attached very bright strobe light which had been intended to capture attention caused some research participants to avoid looking in the direction of the warning sign because of the strobe's intensity. Such glare sources can cause light adaptation (or a decrement in dark adaptation) which makes it difficult to see dimmer objects. Another consideration with respect to natural lighting is that the amount and direction of light can vary with the time of day and with the seasons. Other environmental conditions that can have effects similar to low illumination include the presence of smoke, fog, rain, and humidity (see, e.g., Lerner and Collins, 1983).

#### *Duration/flash rate*

Sometimes a warning is a simple visual stimulus such as an indicator light on an automobile dashboard. Such lights usually stay 'on' until the problem is corrected or the circuit disengaged. The continued presence of an indicator light increases the likelihood that individuals will detect it, but it does not ensure detection. Better than continuous indicator lights are flashing lights. Flash rates of around 10 Hz are recommended by Sanders and McCormick (1993). The flash rate should not be greater than the critical flicker fusion frequency (i.e., 24 Hz), as this produces the appearance of continuous light. If flash rates are very slow, it is important that the 'on' time is long enough that an operator will not miss the light when glancing at the display panel during its 'off' time.

#### *Brightness contrast*

One of the factors influencing whether we can see a stimulus in a particular environment is the figure–ground relationship. In a good figure–ground relationship, the figure or object is readily discernible from the background context. Discernibility is facilitated by brightness contrast, which is a function of reflectance ratios of the figure and ground. Black print on a white background or white print on a black background provides maximum brightness contrast, while gray print on a similar shade of gray background produces little contrast. Research shows that features with greater contrast are detected and localized faster than those of lower contrast (e.g., Brown, 1991; Sanders and McCormick, 1993). Lighting conditions can also affect brightness contrast. In particular, extremely dim and extremely bright light can reduce the apparent difference in light reflectance between the figure and ground.

### *Color contrast*

Certain color combinations produce contrast that is nearly as good as black and white (e.g., black on a saturated yellow or white on saturated red). However, certain hue combinations (e.g., dark blue on dark purple or yellow on white) do not produce distinguishable figure–ground patterns and should not be used (Sumner, 1932).

Some individuals have color-vision deficiencies. Some of these persons are unable to distinguish readily between certain colors, such as between red and green or between yellow and blue because of a genetic defect. These color combinations should be avoided as figure–ground combinations.

In recent years, fluorescent-type colors have become available. Previously, fluorescent pigments tended to fade relatively quickly from exposure to environmental elements such as sunlight. Fluorescent colors interact with ultraviolet light making them appear brighter than nonfluorescent colors. In the US, fluorescent orange is now being used in many localities in signs for road construction/work zones and strong yellow/green has been used for pedestrian-crossing signs. Recent studies show benefits of fluorescent colors in warning applications (Dutt, Hummer, and Clark, 1998; Zwahlen and Schnell, 1998). Unfortunately, not all colors are available as a fluorescent. The fluorescent red is not really red; it is pink. Additional research is needed to determine the benefit of fluorescent colors with respect to their use on product labels (Wogalter, Magurno, Dietrich, and Scott, 1999).

Concern with brightness and color contrast should not be limited to the warning itself, but consideration should be given also to the predominant colors in the environment that will surround the warning. For example, in a largely red environment or context (e.g., the walls of a building, or the main parts of a product label), a red warning will be less noticeable than other colors (Young, 1991). Fullest advantage should be taken of color contrast to distinguish the warning from other colored surrounding stimuli.

### *Highlighting*

Research indicates that when warnings are embedded in other text some form of highlighting (usually with color) helps make them stand out. Strawbridge (1986) found that participants using a glue product were more likely to notice when the embedded warning was highlighted. Young and Wogalter (1990) found that participants who were preparing to use a gas powered electric generator or a natural gas oven were more likely to remember and understand highlighted compared to nonhighlighted warning material in product manuals.

### *Borders*

Another way to highlight safety information is to surround the warning with a distinctive border. Some research suggests that having a border around a warning sign or label enhances figure–ground differences (e.g., Ells, Dewar, and Milloy, 1980; Rodriguez, 1991). Rashid and Wogalter (1997) found that certain border conditions (e.g., having thick, colored diagonal stripes) were rated to be more attention-capturing than other border conditions (e.g., no border or a thin black line border). Example borders are shown in the next chapter (**see Figure 8.10 in color section** from Chapter 8 by Leonard, Otani, and Wogalter). Further, Wogalter and Rashid (1998) manipulated the border of a posted warning placed at a high volume pedestrian area. Their results replicated the pattern found in the earlier rating study. However, positive results have not always been found. Laughery, Young, Vaubel, and Brelsford (1993) did not find an effect of a rectangular border around a warning in a reaction time search task. Swiernega, Boff, and Donovan (1991) observed that the presence of a border slowed performance in a rapid recognition task. The latter result may be similar to a perceptual effect called lateral masking, in which it has been found that stimulus markings presented close in time and distance to target stimuli interfere with the ability to distinguish their features (Averbach and Coriell, 1961).

### *Size*

Large objects tend to be more salient than smaller objects, and are more likely to capture attention. Highway signs are massive to ensure that drivers will see them at distances that allow enough time to attend to them, and if necessary, react to the message. Obviously, we cannot have billboard-size warnings everywhere, but the point is that generally greater size within existing constraints is desirable.

### *Signal word panel and multiple feature combinations*

The ANSI (1991, 1998) Standards on sign and label warnings recommend that all warnings contain a signal word panel on the uppermost portion of the display. ANSI-style warnings include a rectangular-shape signal word panel on the top section. This panel usually includes a signal word (e.g., DANGER, WARNING, CAUTION), color (e.g., red, orange, yellow), and a signal icon/alert symbol (a triangle enclosing an exclamation point) or some other shape (e.g., oval, hexagon) which together comprise a multiple-feature configuration (e.g., Westinghouse Electric Corporation, 1981; FMC Corporation, 1985). Examples are shown in **Figures 7.1 and 7.2 (see color section)**. These stimuli were tested by Wogalter, Kalsher, Frederick, Magurno, and Brewster (1998d). This research is detailed in the next chapter.

Although there has been considerable research on the panel's components, individually and in combination, most of it has concerned measurement of hazard connotation (Chapanis, 1994; Kalsher, Wogalter, Brewster, and Spunar, 1995; Wogalter *et al.*, 1995b, 1998d; see also Chapter 8 by Leonard, Otani, and Wogalter). Relatively few empirical studies have investigated the attention attracting effects of the signal word and other associated components. Laughery *et al.* (1993), using reaction time measures, found that an alcohol warning printed in red with a signal icon was detected on labels significantly faster than a black warning without a signal icon. Similarly, Bzostek (1998), using pharmaceutical labels, found that warning detection was significantly faster when they contained a colored signal word (that distinguished it from other text), and/or contained one of several icons.

Generally, warnings having more prominence-type features are more salient and easier to find and more likely to be noticed than those having fewer prominence-type features. Multiple features provide several cues that individually or in combination could capture attention. Additionally, warnings with multiple salient features should benefit people with sensory or perceptual deficiencies. For example, persons who are color blind might not distinguish some of the colors but may notice the warning because of the bold printing of the signal word or shapes that are used. Additional research on the relative added value of the various prominence features, separately and together, is needed to give warnings designers a better basis upon which to make decisions.

### *Pictorial symbols*

Another component of many multi-feature warnings is pictorial symbols (or icons). Most research on pictorial symbols concerns comprehension, a topic that will be covered in Chapter 8 by Leonard, Otani, and Wogalter. However, a frequently overlooked benefit of symbols is that they are attention getting also. Research shows that warnings with pictorial symbols are rated more noticeable (Kalsher, Wogalter, and Racicot, 1996; Sojourner and Wogalter, 1997, 1998) than warnings without them. Research also shows that a warning that includes an icon is easier to detect (Laughery *et al.*, 1993). The attention-getting benefit of symbols might have little or no dependence on their understandability. Thus, even if a symbol is not highly understandable, its inclusion in a warning might still be warranted as long as the critical-confusion errors are low. According to ANSI (1991, 1998), a pictorial symbol should produce no more than 5% critical confusion in a comprehension test. See Chapter 8 by Leonard, Otani, and Wogalter for more discussion on comprehension testing and critical confusion.

### *Location*

In general, warnings should be located so that individuals who need to see them do in fact notice them. The layout of the environment and what people do in the environment need to be considered in placing a warning properly. Determining the best location(s) may require task analyses (e.g., Lehto, 1991; Frantz and Rhoades, 1993), where the work or other tasks are broken down into cognitive and motor units and are analyzed to determine the locations where people tend to focus their visual attention as they perform the work or other activity. See Chapter 13 by Frantz, Rhoades, and Lehto for a more detailed discussion on task analysis.

In general, a warning's attention-getting power will be facilitated by placing it close to the hazard. Thus, in most cases warning noticeability will be benefited by its attachment directly to the product (or its container) as opposed to a more 'distant' placement such as in a separate instruction manual (Wogalter *et al.*, 1987; Frantz and Rhoades, 1993; Racicot and Wogalter, 1995; Wogalter, Barlow, and Murphy, 1995a). Although this recommendation is reasonable in most cases, in certain circumstances a warning placed too close to the hazard can be ineffective and sometimes dangerous. An example would be a roadway work-zone sign that is first visible close to or within the work zone itself. A better placement would provide sufficient advance notice about the upcoming hazard. The warning should not be too distant, however, as it might be forgotten. Analysis of the task and foreseeable circumstances can help to reveal one or more potentially appropriate placement locations to enhance warning noticeability (see Chapter 13 by Frantz, Rhoades, and Lehto).

Most people's relaxed looking angle for straight-ahead viewing is between 15° and 35° below horizontal straight ahead of them. Warning locations considerably different from where people tend to look, such as higher (or lower) in the horizontal periphery will be less likely to be noticed (Cole and Hughes, 1984).

Sometimes warnings cannot be placed at optimal locations. For some products and environments, aesthetics need to be considered. For example, people would not like having a highly conspicuous warning displayed on the front panel of a stereo receiver in their living room entertainment system. Where else might a warning for the stereo receiver be properly placed? Some potential locations are better than others. For this example, suppose a warning is needed for hazards associated with improperly connecting peripheral components to it. Besides the front panel, other potential locations for this warning could be on the top or the rear of the receiver's case. A warning at these locations would be apparent to users connecting the cables. The rear location is better than the top because people installing the receiver probably would be looking at the back panel when performing the wiring task, whereas the top might be obscured by another stacked component (and it may be considered aesthetically displeasing). The bottom of the receiver is a poor location, because most installers would not see the warning label when doing the wiring. However, the underside could be an appropriate place to put certain other kinds of warning message (e.g., a warning intended to prevent unqualified persons from removing the cover). This would be a good location for this warning because the screws are located there. Another potential location is in the product manual. Certainly warnings belong there because people may assume that the manual contains a complete listing of all relevant hazards. However, if it is a very important warning (e.g., because of severity, frequency of occurrence, etc.), then the warning should be located also on the product itself (or container of the product), because people may not read the manual or may not have it available at all. Nevertheless, sometimes poor placement options can be compensated for when used in conjunction with a well located brief accessory warning (e.g., on a front panel of a product) that directs them to look at another specific location for more detailed information (Wogalter *et al.*, 1995a). Because there is no guarantee that every person will look where we think they will look, placing important warnings in multiple locations (e.g., both on the product and in a product manual) will increase the chance that one of them will be seen.

### 7.2.2 Audition

For the purposes of this chapter, we will assume that any sound stimulus, whether simple or complex, can alert and attract attention (unless masked by other sounds). Complex sounds, like voice, also have the potential of conveying general or specific information on what the problem is. In this chapter we will not be discussing the processes involved in comprehending the intended meaning of complex sounds (see Chapter 8 by Leonard, Otani, and Wogalter).

Auditory warnings are used commonly to alert people to various problems. Even relatively simple sounds, such as sirens, tones, buzzers, bells and whistles, produce an alerting reaction and sometimes a startle response. Sounds like these are a powerful way to get people's attention. Good warning alerts will arouse people from tasks on which they are highly focused. This 'kick-in-the-head' alerting characteristic makes auditory warnings a favorable tool for attracting attention.

Another major advantage of auditory warnings is the omnidirectional nature of most sounds (Wogalter and Young, 1991; Wogalter *et al.*, 1993a). Auditory signals spread out in all directions from the source, usually reflecting off multiple surfaces before arriving at the receiver's ears. Thus, unlike visual warnings, persons at risk need not be looking at a specific location to be alerted.

Although sounds spread out, they can give directional cues also. Generally, mid to high frequency sounds direct to the ears from the source can provide location cues based on small differences in the time of arrival and intensities of certain frequencies of the sounds between the two ears. For example, a tone coming from a speaker on a control panel can cue the operator to attend to a particular visual display on the panel so that the specific reason for the auditory signal can be determined (Eastman Kodak Company, 1983; Sorkin, 1987; Sanders and McCormick, 1993). Unfortunately, location detection is poor in some circumstances. The sirens of emergency vehicles often are hard to localize amongst walls of city buildings, and can be particularly confusing when a single window of a car is open but the sound source is actually emanating from the opposite direction.

The human auditory system is more sensitive to some sounds than others. The frequencies of the human voice are those for which the auditory system is most sensitive (1000–4000 Hz) (Coren and Ward, 1989). It might be assumed that one would want to provide the auditory warnings within this frequency range because of our increased sensitivity to them. However, warning signals within this range could interfere with the reception of relevant verbal discourse in an emergency situation (which, too, might carry warnings). Thus, an important aspect for the auditory alert signal is that it be comprised of frequencies different from the expected non-warning sounds in the environment, as well as other warning sounds, that might mask it. While the warning(s) should be different from other sounds, it should still be within the sensitive regions of the frequency spectrum.

The above discussion indicates that interference is an important consideration in the design of auditory warnings. There are three kinds of interference of concern. One is masking by noise or other signals that cover up or obscure parts or all of the sound. Background noise, such as machinery in an industrial environment and music blaring in vehicles, can vary in loudness, frequency and complexity. Where possible, the warnings designer should consider whether and how other sounds might affect the auditory warning's signaling ability.

A second type of interference is attenuation (reduction in intensity). Ear protection (e.g., plugs, muffs) is used in many industrial work environments to shield workers from loud extraneous sounds and to prevent hearing loss. Closed car windows also attenuate sounds from outside the car, including sirens from emergency vehicles. Thus, auditory warnings need to be designed to be heard distinctly above the expected background din or within sound shielded conditions. One potential solution in industrial settings is to include headphone speakers inside ear muffs to allow information to get through electronically. Similarly, in automobiles and other enclosed spaces outside signals can be transmitted to within the shielded environment.

A third kind of interference is distraction of the receiver's mental processing by the warning itself. The considerable alerting value that makes auditory warnings useful for capturing attention can be a hindrance when it gets in the way of (distracts from) a very critical task—such as making corrections to the problem the warning is signaling. A loud blaring buzzer from a cockpit warning might interfere with a pilot's ability to carry out proper emergency maneuvers. The more intrusive a sound is, the more likely it will interfere with thought processes. Further, very loud sounds can cause threshold shifts which can cause temporary or permanent reduction in the ability to detect subsequent sounds (Ward, Glorig, and Sklar, 1958; Kryter, Ward, Miller, and Eldredge, 1966).

Thus to attract attention a warning should be louder and spectrally different from the expected background noise, but also it should be given at frequencies for which we are sensitive. At the same time, it should not be so loud that it distracts the listener from performing important tasks. Therefore, numerous foreseeable conditions must be evaluated when designing an auditory warning system to attract attention.

## 7.3 ATTENTION MAINTENANCE

A warning does little good if it just captures attention but the person gets nothing out of it or the person immediately redirects his or her attention to something else. Once attention has been attracted to the warning, it is important that the warning retain attention so that information can be encoded (see also Rousseau, Lamson, and Rogers, 1998). During this active attention period, the message text is read and/or the pictorial is examined. The warning must hold attention for the time necessary to encode and store the message contained in the warning. The warning should prevent attention from being distracted by and to other stimuli before the message is satisfactorily encoded. These processes involved in knowledge and comprehension are covered in Chapter 8 by Leonard, Otani, and Wogalter. As we did in the section on attention capture, we discuss the visual and auditory factors involved in attention maintenance.

### 7.3.1 Vision

If the warning is difficult to read because individuals have difficulty making out the letters comprising the words, they are less likely to devote the time and energy necessary to decipher them. In this case, the warning fails to maintain attention. An important factor for maintaining attention to a visual warning is legibility. Legibility refers to how well the separate features or markings of letter characters and pictorials can be distinguished so that they can be identified and recognized. Some writers have mistakenly confused legibility with readability. Both are concerned with ease of reading. However, readability concerns larger groups of characters (e.g., words, sentences) in which comprehension of the material is a consideration (see Chapter 8 by Leonard, Otani, and Wogalter). Legibility concerns whether the individual characters and their features are distinguishable. It concerns the way the text looks; whereas, readability concerns its content or meaning.

#### *Size and visual angle*

Frequently legibility is tied to size or, more specifically with respect to text messages, to letter height. Underlying the visual size dimension is visual angle (Smith, 1984) which relates to the area occupied on the retina by the feature's image. With a small retinal image, fewer receptors register the individual components, resulting in poorer visual acuity. If the visual angle is very small, the viewer may see a gray blur instead of separate dark and light elements. The visual angle is a function of both the stimulus size and its distance away from the eye. At greater distances, a given stimulus produces a smaller image than if it were closer. If users are expected to hold a product while examining its label, then the size of the letter characters should be based on the expected distance from the hand-held label to the eye. Letter heights for a 'Keep Out' sign at an electric utility power station should be based on the distance from the sign to the peripheral approaches to the site.

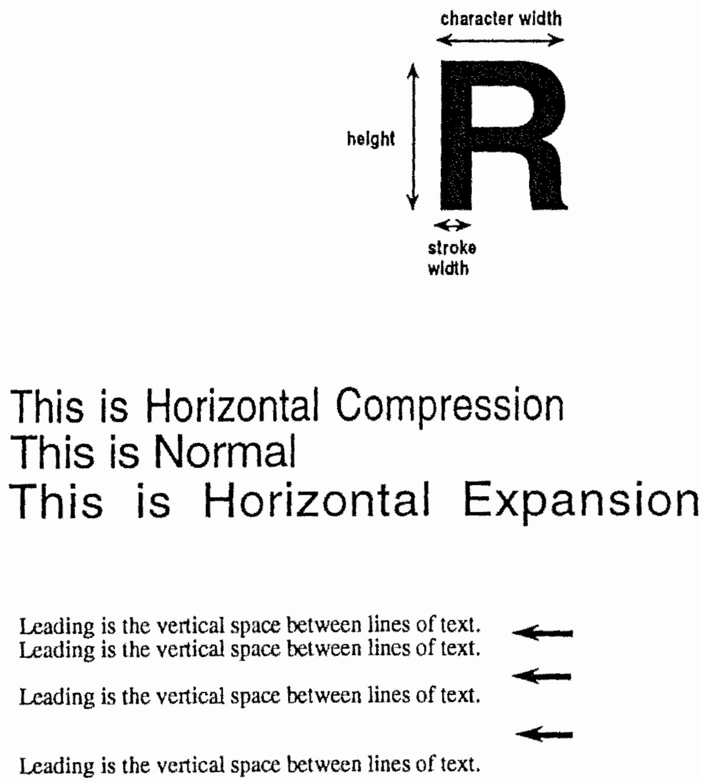


**Figure 7.3** Example typographical characteristics.

While generally large print is preferred to small print, there are limits. There cannot be monumental warnings everywhere. If people are able to read the warning under all foreseeable risk conditions, then the print does not need to be any larger. If the print is too large it will be difficult to encompass the information in a glance.

There is more to recognizing characters than simply their height. Other factors include the thickness of the character stroke, height-to-width ratio, character compression, and leading. Figure 7.3 illustrates these characteristics. See Tinker (1963) and Sanders and McCormick (1993) for more information on these and other typographical characteristics.

Sometimes warnings are printed in all upper case (capital) letters. Given the same point size, upper case letters are physically larger than lower case letters as in the following example:

Warning versus WARNING

Because of their generally smaller size, lower case letters produce smaller visual angles than larger upper case letters. By considering only character size, upper case letters might be more legible than lower case letters (Foster and Bruce, 1982). However, experts on typefaces have noted that mixed-case materials (both upper and lower case) are easier to read (Tinker, 1963; Williams, 1994). Lower case letters are more distinctive in shape, thereby making them easier to differentiate than upper case letters. Upper case letters have a block-like appearance making them highly similar and confusable with one another under low-legibility conditions (e.g., small visual angle, low illumination). Garvey,

**Figure 7.4** Example of a nearly illegible pictorial symbol. It is supposed to mean 'no eating, drinking or smoking'.

Pietrucha, and Meeker (1998) compared the font Clearview to the fonts on standard highway signs. Clearview's lower case letters are 12% larger than the standard font. They found that increasing the physical size of the lowercase letters (but still using the same 'footprint' space as the standard font) produced better recognition and reaction time scores than the standard font.

Research has shown that under certain conditions reducing the space between individual letter characters enhances reading speed (Moriarity and Scheiner, 1984). When the print is above threshold legibility, closer-spacing of characters requires fewer eye movements to read. However, character spacing must be adequate for the letter components to be seen distinctly. This might account for why Anderton and Cole (1982) and Young, Laughery, and Bell (1992) found that reduced spacing between letters reduced legibility. Watanabe (1994) also found horizontally compressed characters were less legible.

### *Font*

Font style can affect legibility particularly when highly elaborate, unusual, unfamiliar fonts are used. The ANSI (1991, 1998) Z535 Standards recommend sans serif fonts (without character embellishments) such as Helvetica over fonts with serifs (with character embellishments) such as Times Roman. Serif fonts are considered acceptable when the font size is small (as in many product labels and most manuals). Proof readers report serif fonts to be less fatiguing than sans serif fonts. Serif fonts facilitate reading under low contrast conditions because the serifs aid in letter distinguishability, and by putting more ink on the page. The presence or absence of serifs probably does not have a substantial effect as long as the font style is not extremely unusual or elaborate.

### *Symbols*

As we have suggested earlier, the relevant features of pictorial symbols need to be legible. Too much detail can make a graphic illegible when it is reduced in size or viewed at a distance. Most design standards and guidelines recommend using large bold components in safety symbols. However, large blobs of ink can render a pictorial symbol illegible. Figure 7.4 shows a pictorial symbol with legibility problems.

A frequently used graphic shape in warnings is the prohibition or negation symbol. This symbol is a red circle with a single diagonal slash going from the top left quadrant to the bottom right quadrant. Usually the negation symbol is configured so that the slash overlays another symbol placed within the circle (but occasionally the slash is placed under the symbol or an X is used instead). The intended meaning is to prohibit whatever the internal symbol depicts. **Figure 7.5 (see color section)** shows an instance where, on the same street corner in San Francisco, both the over and under slash are used.

It is particularly important that the over slash or X does not obscure the critical details of the underlying symbol necessary for its interpretation. Dewar (1976) and Murray, Magurno, Glover, and Wogalter (1998) found that sometimes the slash can obscure critical features of symbols, decreasing their recognizability. Murray *et al.* (1998) showed that simple adjustments, such as horizontally flipping asymmetric pictorials, can aid identification performance. Examples are shown in **Figure 7.6 (see color section).**

### *Figure–ground contrast*

As with attention capture, figure–ground contrast is important for attention maintenance. Legibility is reduced when the contrast between the characters relative to its background is low. Ideally, the print and background should be comprised of dark print on light background (or vice versa, light print on a dark background) or of two highly distinguishable colors (e.g., red on yellow or vice versa) rather than two shades of gray or two similar shades of another single color.

### *Environmental conditions*

The presence of smoke, fog, rain, reduced light, etc. can limit the discernibility of the individual warning features (e.g., Lerner and Collins, 1983). Another environmental-related concern is that the color red, the most important hazard color, does not maintain its hue well under dim lighting. As light is reduced, red darkens in appearance before the other hues do, thereby reducing its contrast with dark backgrounds. For expected dim lighting conditions, red printed on a light background is preferred. Another frequently used safety color, orange, can get washed out under certain kinds of artificial lighting.

### *Printing*

Legibility can be affected adversely by poor reproduction at the printing stage where wet paint or ink may spread or 'bleed' and sometimes fill in important details that would otherwise help to distinguish the characters. A similar problem can occur with projected light displays (e.g., on computer screens). Here the stroke width of light letters on dark backgrounds generally needs to be somewhat thinner than for dark letters on a light background. Light comprising the letters spreads out making the stroke width appear wider than it is; this phenomenon is called irradiation (Sanders and McCormick, 1993).

### *Durability*

Over time, exposure to sunlight, air pollution, dirt, grime, water, cold, and heat could cause the color and brightness contrast of the pigments and the material comprising the warning to degrade, making the warning less legible than when it was newer and in better condition. Also, colors degrade at different rates. Red and magenta pigments on outside signs fade more quickly than other colors, primarily from exposure to the sun and other environmental elements. This can create a serious problem beyond simply making the warning more difficult to detect.

Consider what can happen with negation-type symbols where the red of the circle/slash may fade faster than the black. As a consequence, the 'inside' portion of the symbol may be seen clearly while the 'red' prohibitive portion may not. **Figure 7.7 (see color section)** shows a photograph of a 'no pedestrian crossing' symbol sign where the red circle/slash negation portion has completely faded. In this case, people might interpret the exact opposite of the intended meaning!

The conditions under which the label or sign can reasonably be expected to be used and stored must be considered when choosing materials. The warning must remain in a satisfactory condition over the expected existence of the hazard. Moisture on a paper label will cause it to disintegrate, and some glue compounds will break down with extreme temperatures. The print pigments and the materials constituting the warning should be chosen so they remain in good condition throughout the effective life of the sign or product. Therefore, one should not simply assume that a warning will hold up for the entire time that the sign or the product is in use. Hazard signs (and where applicable, product labels) should be inspected, maintained, repaired, or replaced. In commercial and industrial settings, signs and labels should be inspected periodically. The warnings should be repaired when the materials degrade, become dirty, or are vandalized. Such procedures also provide the opportunity to replace the old warning with a newer version if new materials, designs, and information have become available since its original placement. We recommend the warning designer seek professional consultation in determining the materials that will preserve it over time and in foreseeable conditions of use and abuse.

### Target audience

Legibility also depends on the target audience. The persons at risk might have an assortment of vision problems, most notably uncorrected vision with acuity worse than 20/20. For example, older individuals as a group are more likely to have vision problems (Rousseau *et al.*, 1998), and are more comfortable with and prefer larger size type than younger adults (Vanderplas and Vanderplas, 1980; Zuccollo and Liddell, 1985).

### Formatting

The appearance of the warning can influence whether individuals will choose to maintain attention to the material or look elsewhere. Desaulniers (1987) showed that people were more willing to read text structures arranged in an outline or list format, with spaces and bullets separating the main points, instead of continuous paragraph-type prose. We suspect that this result is due partly to people being more likely to look at and examine aesthetically pleasing material.

### Location

Warnings should be placed so that people can read and examine them comfortably. A posted sign warning that is positioned at an angle, instead of straight on, can be more difficult to see and may discourage further looking. One illustration of this is the warning on one department store brand of top-load washing machines. The lid is hinged on the left side, and printed on the underside of the lid is a set of operating instructions and warnings. In order to read the horizontal print straight on while standing in front of the machine, one must cock the head sideways over the machine. Few people will make the effort to get into this awkward position to read the material.

### *Limited space*

In many situations the types of information and feature that can be included in a warning are constrained by the space available. Limited space is a particular problem for products that have multiple hazards and are held in small containers. A complete warning of all hazards on the label would force the use of very small print, and consequently legibility would be reduced and fewer people could or would read it. Therefore, on some hazardous products one cannot print everything of relevance on labels directly attached to the product. Nevertheless, several alternative strategies can be considered in dealing with this limited space problem. One alternative is to select certain information for emphasis (Young, Wogalter, Laughery, Magurno, and Lovvoll, 1995) and exclude less important information. The abbreviated warning label could refer users to a more complete set of information in some other location (Wogalter *et al.*, 1995a). This strategy may be acceptable if indeed complete information is actually available. Ready access to product manuals cannot be guaranteed as some are thrown away or lost after the product is first used (Wogalter, Vigilante, and Baneth, 1998c).

A second alternative is to increase the size of the label or sign to allow for more information, and/or larger print. Highway signs are sized to enable motorists to see the information legibly at a distance. Additionally, research shows consumers prefer a glue product having a container label design that increases the label's available surface area to make room for a larger warning compared to a more conventional label design with a smaller warning (Barlow and Wogalter, 1991; Wogalter, Forbes, and Barlow, 1993b; Wogalter and Young, 1994; Wogalter and Dietrich, 1995; Kalsher *et al.*, 1996). Several alternative methods for increasing label space on small glue and pharmaceutical containers have been examined including a tag, wrap-around, and cap label designs (Wogalter and Young, 1994; Wogalter *et al.*, 1999). Figure 7.8 has three example container label designs having additional surface area that could be used for larger print and/or additional material. Research has shown that people (particularly older adults) prefer container label designs such as those shown in Figure 7.8 and acquire more information from the label. There is also higher compliance than with conventional container label designs.

### *Integration or separation from instructions*

Most products come with information on how to operate, maintain, and service the equipment, in addition to warning about hazards. How warnings should be presented with respect to procedural instructions and other information has been debated and frequently has been the subject of guidelines by various groups. The Environmental Protection Agency (1991) and other US agencies have suggested that precautionary statements should be in a distinct section separate from the instructions. However, research shows some conflicting results on whether warnings should be separated or integrated with the operating instructions. Friedmann (1988) noted that many individuals skipped the warning to go to the procedural/operating instructions. Venema (1989) found that twice as many individuals reported that they examined product labels for the purpose of reading the operating instructions than to read about safety instructions. Strawbridge (1986) found that more individuals read the warning on a glue label when it was placed together with the instructions. Additionally, Frantz (1992, 1994) found greater warning compliance if the warnings were included within the instructions, as compared to separate sections of warnings and instructions. Other studies have found different results. Karnes and Leonard (1986) found a positive effect of a separate warning section, but this finding is complicated by the fact

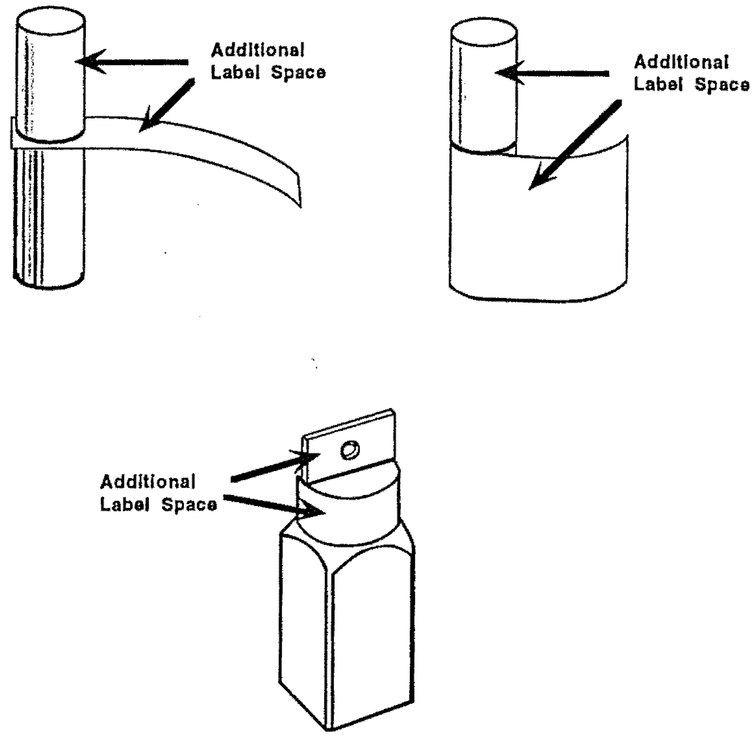


**Figure 7.8** Example bottle label designs where there is additional surface space for larger print and/or important/additional material.

that the separate warning differed somewhat from the embedded version. Wogalter *et al.* (1993a) found that a warning within a set of instructions was complied with more frequently than a (larger separated) sign warning. In another study, Wogalter, Mills, and Paine (1998b) manipulated the format of risk information in the consumer portion of prescription drug advertisements. They found that a separate enhanced warning similar to the style recommended by the ANSI (1991, 1998) guidelines produced higher knowledge scores in a comprehension test than either a simple separated or integrated warning.

As the above descriptions indicate, research on integrated versus separated warnings has produced equivocal findings. Probably some of the differences are attributable to familiarity with and the complexity of the product or task and the perceived risk. Products and tasks perceived to be familiar, simple, and of low risk produce less concern than those perceived to be less familiar, complex and of high risk (Wright *et al.*, 1982). With greater familiarity, separate highly conspicuous warnings placed at strategic locations might be better than warnings integrated with the instructions. In the less familiar case, people are likely to go through the instructions step by step and, consequently, it is probably better to integrate the warnings with the operating instructions. These speculations, however, need to be verified.

### 7.3.2 Audition

An effective auditory warning alerts the receiver but after attention is captured, attention to the auditory stimulus may need to be maintained over time in order to process message content. This is not an issue for short duration stimuli, yet even here attention might still need to be held (e.g., to the representation in memory). With long duration auditory stimuli (e.g., a voice message), attention must be held while the message manifests itself. For the most part, attention maintenance in the auditory realm involves voice communications, as speech more frequently requires across-time processing than most nonverbal auditory stimuli.

### *Intelligibility*

The concept of intelligibility of auditory stimuli corresponds to the concept of legibility for visual stimuli. A large body of research exists on the factors that influence intelligibility. Most of the work was done in military and aviation contexts. Some of the most important factors are described below.

A perfectly clear message at the source can be made unintelligible if played back through defective or low fidelity systems. Many people have had the experience of unsuccessfully trying to decode the speech of an order taker at a restaurant drive-through. Defective equipment (e.g., a blown loudspeaker) makes it difficult to discern the different speech components. Of course, the problem may be the order taker's enunciation, too! A person who speaks with a heavy foreign accent or with a speech impediment also decreases intelligibility.

In addition to above-noted effects attributable to the source of the message, intelligibility can be affected also by numerous other factors related to the channel, context, receiver, and the message itself. Intelligibility is reduced by (a) low level signals, (b) the presence of high levels of masking noise, (c) the receiver's low familiarity with the message, (d) a wide ranging possible vocabulary from which the message is conceived, (e) low redundancy of the sound components, (f) very fast or very slow rate of transmission, and (g) high similarity of the target voice relative to other background sounds/voices. Two excellent reviews of this literature are provided by Edworthy and Adams (1996) and Sanders and McCormick (1993). Additional information can be found in Mulligan, McBride, and Goodman (1984).

### *Annoyance and false alarms*

As noted earlier, auditory warnings can annoy people. Highly intrusive sounds can interfere with the receiver's thought processes making some activities more effortful and error prone. Also people can become quite disturbed when too many false alarms occur. High rates of false alarms happen when the detection system's sensitivity is very high. Usually there is good reason for making a safety system highly sensitive, for example when the hazard could produce devastating results. Most people want airport bomb detectors to be highly sensitive so that no explosives make it onto passenger aircraft even though more people and baggage are searched causing delays and frustration among travellers. These efforts are worth the trouble, given the possible consequences. Besides the annoyance problem, high false alarm rates can produce the 'cry wolf' phenomenon—people ignore the warning signal because they believe that it is false. Unfortunately, the warning might actually be properly signaling a true hazard, producing tragic consequences. Frequent false alarms can increase the likelihood that people waste time searching for a way to eliminate the warning rather than trying to correct the condition which caused the warning, and purposely attempting to defeat the system. In some cases, elimination of the condition causing the signal may be simple, such as buckling lap belts or closing an unlatched car door by slamming it shut. In complex industrial environments, it may not be so simple. A means of turning off the warning might be needed. Of course the system should be designed so that if the warning is turned off, it would be automatically reset (perhaps after a short delay) so that it is available for any recurrence of the problem. Ideally, an auditory warning should always sound when it is needed and never when it is not.

*Multiple voice warnings*

Some systems employ multiple voice warnings. The problem is that some of these systems do not account for the possibility that they might be deployed simultaneously, a situation which could be highly confusing to the operator. How do you deal with the possibility of several simultaneous speech warnings? Some possibilities are: (a) presenting simultaneous messages in distinctly different voices that are discriminable from one another (male versus female versus synthetic voice); (b) prioritizing the order of messages so that the most important are given first; (c) having messages appear to be coming from spatially distinct locations; (d) giving the most important message(s) prominence features (e.g., loudness) based on urgency; (e) enabling playback of the message if part of it is missed the first time; and/or (e) combining a concise voice warning with a more detailed print warning (Wogalter and Young, 1991; Wogalter *et al.*, 1993a; Edworthy and Adams, 1996). In the latter case, the voice warning can serve to capture attention, concisely present the most important information, and then orient the person to a more detailed visual warning.

## 7.4 OTHER FACTORS AND ISSUES

### 7.4.1 Multi-modal warnings

As noted above, sometimes auditory and visual warnings can be combined. A benefit of having both types of warnings in a warning system is that they provide redundant cues. If one modality for the warning is blocked, information is available in the other modality. Visual and auditory cues can be combined also with cues from other sensory modalities, including smell, taste, and tactile/kinesthetic. The smell of smoke, the taste of something bitter, or the rumbling of a car over paving strips, are examples. Corrugated-pavement strips on roadways provide auditory and tactile alerting cues to reinforce the visual cues from the road and from signs indicating a reduced speed limit or imminent hazard.

Another example of multi-modal cues is interactive warnings (e.g., Hunn and Dingus, 1992; Dingus, Wreggit, and Hathaway, 1993; Frantz and Rhoades, 1993; Duffy, Kalsher, and Wogalter, 1995; Wogalter *et al.*, 1995a). Interactive warnings provide tactile/kinesthetic (touch) cues while the participant is performing a task (such as having to touch and move a warning while installing or using a product). Theoretically, interactive warnings cause a break in the performance of a familiar task by causing attention to be switched to the warning (Gill, Barbera, and Precht, 1987; Rasmussen, 1987; Lehto, 1991; Frantz and Rhoades, 1993).

### 7.4.2 Overloading

Overloading occurs when the amount of information is more than a person is able or willing to process. Many separate warnings or a single extensive one will be less likely to attract and maintain attention than having a few brief warnings. Prioritizing hazard communications is critical (Vigilante and Wogalter, 1997). To reduce the possibility of overloading or excessive on-product warnings, the most important information should be placed on the product and less relevant material placed in an accompanying product manual or package insert (see also Wogalter *et al.*, 1995a).

Overloading should not be confused with overwarning. Overwarning is the notion that people encounter too many warnings in the world, and it is thought that people will be less likely to attend to warnings as a consequence of this inundation. In other words, overloading means that processing capacity is overwhelmed or exceeded by the amount of information in a given situation, whereas overwarning involves being habituated by one's overall life experience. Although overloading and overwarning are theoretically possible, research has not yet verified their occurrence clearly. Nevertheless if either occurs, it means that there should be even greater emphasis on prioritization of content, formatting, and placement.

### 7.4.3 Habituation

In Chapter 2 by Wogalter, DeJoy, and Laughery, the communication-human information processing (C-HIP) model was described as having a nonlinear flow of information among the processing stages. It was noted that later processing stages in the model feed back onto the attention stage (in a loop-type fashion). One example of this is habituation. Habituation is an outgrowth of the mental events described at the outset of this chapter. Initially, attention is attracted to the most salient stimulus and, while it is maintained on the stimulus, memory is formed causing the stimulus to become less salient. As a consequence of this reduction in salience, other stimuli of greater relative salience will attract attention away from the warning stimulus. Habituated warnings have inadequate salience to attract and maintain attention.

In a different, and perhaps less obvious sense habituation indicates that there is some information about the warning in memory. However, this does not mean that all of the relevant information is known. Individuals might have incomplete knowledge yet not be motivated to seek additional information.

Several design factors may help to retard or counteract habituation. The first is to incorporate the prominence features (size, color, loudness) described earlier in this chapter. Another method is stimulus variation. This can be done by modifying the warning periodically so that it looks or sounds different. Technology has now enabled control and presentation of many signs so that warnings are presented only when they are needed. One example is electronic signs on busy roadways. In the workplace and in hazardous environments, warnings could be presented at the points in time when risky behavior might be exhibited. Highly sophisticated detection and warning systems could enable personalization of the sign also (e.g., using the targeted individual's name) and varied presentation patterns (partial, irregular reinforcement) that will prevent or delay habituation (Wogalter, Racicot, Kalsher, and Simpson, 1994; Racicot and Wogalter, 1995).

Unfortunately, changing the warning is not always possible. Product manufacturers cannot visit people's homes and alter the warning label on their appliances and power tools every so often. However, some kinds of stimulus change on consumer products are possible. One is to change the styles and formats of warning labels on frequently purchased (nondurable) consumer products according to some regular schedule. For durable goods such as appliances and power tools, it may be possible to send revised warnings to consumers for previously purchased products using data bases containing purchase, rebate/coupon, warranty, and repair records.

### 7.4.4 Familiarity

In the last section, we described habituation as an example of a later stage of the C-HIP model that affects the 'early' stage of attention. Habituation involves memory affecting attention. Another example of feedback from a later stage of processing on attention is the effect of familiarity (see Chapter 9 by DeJoy). Numerous studies show that persons familiar with a product or task are less likely to look for or read a warning than those who are less familiar (e.g., Godfrey, Allender, Laughery, and Smith, 1983; Godfrey and Laughery, 1984; Leonard, Hill, and Karnes, 1989; Wogalter, Brelsford, Desaulniers, and Laughery, 1991; Wogalter *et al.*, 1995a).

### 7.4.5 Standardization

There has been an increasing effort in recent years to produce standards that specify certain design characteristics (see Chapter 12 by Collins). An example is the ANSI (1991, 1998) Z535 format described earlier. A positive aspect of standardization is that, given its relatively constant physical characteristics, people will eventually learn what a warning looks or sounds like. In this sense, a standard warning in clutter or in noise might stand out because people will know immediately that it is a warning. A further advantage of standardization is that relatively little effort may be needed to produce a warning that conforms to the standard. However, standardization could produce problems. Unfortunately, these problems have not been thoroughly considered by advocates for standards. The purpose of standardization is to promote similarity across warnings which will exacerbate the habituation problem. If all warnings look or sound about the same, then it is quite possible that over time people will pay less attention to them, and this could have disastrous consequences. We believe that standards and guidelines are good starting points for initial warning designs. But they are minimum standards. There should be flexibility to allow the warning designer to deviate from the standards when it is useful and beneficial to do so. Testing can reveal other design variants that may be better than those specified by the standards. For example, test data might show that for a particularly important warning, the word 'DEADLY' and a diagonal stripe border capture attention better than an ANSI (1991, 1998) warning with the word 'DANGER' and a thin plain black line border. With good data to support them, modifications from the standard's specifications should not only be permitted, but encouraged.

### 7.4.6 Processing Mode and Relevance

A warning will more likely capture and maintain attention when individuals are in an information seeking mode than in other modes of thinking (Lehto and Miller, 1986; DeTurck and Goldhaber, 1988; Lehto, 1991). In other words, a person who is actively looking for hazard-related information, will be more likely to see, hear, and encode a warning than a person who is occupied with other tasks.

Stimuli that are personally relevant and interesting tend to elicit attentional processes. Because people's interests differ, people will look at and listen to different things. Our own name is one of the most relevant and attention-attracting stimuli. Moray (1959) found that auditory presentation of a person's name had a strong effect on attention attraction. Similarly, Wogalter *et al.* (1994) showed that displaying a person's first name on an electronically presented sign led to higher warning compliance with more people donning protective equipment in a chemistry laboratory situation than a generic warning signal word (CAUTION) in its place.

### 7.4.7 Characteristics of the Target Population

As noted earlier, an important concern in developing warnings is the intended target population. In some cases, the target population is the general population; in other cases, the population is more constrained (e.g., healthy, young military recruits). Not infrequently, broad target audiences will contain individuals having some form of limited sensory capability, such as vision or hearing impairments among older adults (Rousseau *et al.*, 1998; Wogalter and Young, 1998). The warnings designer should take care to consider the target audience's characteristics and, where applicable, specify warnings designs that compensate for potential impairments. For example, for older adults, warnings could be made larger or louder (Laughery and Brelsford, 1991; Rousseau *et al.*, 1998).

Impairments also can occur situationally. Attention to a warning can be attenuated under conditions of time stress (Wogalter, Magurno, Rashid, and Klein, 1998a), from physical or mental fatigue, alcohol or drug consumption or illness. If these conditions are likely, then consideration should be given on how they might affect attention and what might be done to compensate for the effects.

### 7.4.8 Testing

How can you know whether a warning attracts and maintains attention adequately? The best way to determine this capability is to test a representative sample of the target population. Other chapters in this volume provide more information about testing methods (e.g., Chapter 3 by Young and Lovvoll; Chapter 13 by Frantz, Rhoades, and Lehto). In this chapter, we mention briefly some of the most pertinent testing factors with respect to attention capture and maintenance. Some of the basic methods include: (a) having individuals rate or rank the noticeability of various prototype designs; (b) having individuals take part in legibility or intelligibility assessments that might include the warnings being presented at a distance or under degraded conditions; (c) assessing memory to determine whether participants remember seeing or hearing the warning; (d) measuring reaction time to detect and find target information in displays with and without a warning (where quicker response times indicate better noticeability); and (e) recording looking behavior to determine whether and how quickly individuals orient to the warning (e.g., eye and/or head movement), and for how long they examine it. The best evaluations are those that most closely replicate the real risk conditions and tasks. For example, measurement of looking behavior using a hidden camera is a more externally valid assessment of warning salience than subjective ratings of warnings presented in a questionnaire booklet.

## 7.5 IMPLICATIONS AND RECOMMENDATIONS

If people are unaware of an existing hazard, they need to be warned about it. First, attention needs to be captured and then maintained on the warning. Highly salient warnings are more likely to attract and hold attention than less salient warnings. Generally, incorporating features that add prominence to the warning is desirable. The exception to this rule is when attention to a warning adds danger to the situation. Examples include warnings that divert a pilot's attention away from highly critical displays during takeoff or a flashing dashboard light that draws a motorist's attention away from the road.

In this chapter we focused on the factors that influence the switching and holding of attention to warnings presented in the visual and auditory modalities. For visual warnings, we considered contrast, color, size and legibility, surround contours and borders, internal shapes such as pictorials and symbols, location, signal words, limited surface area, degraded environments, and durability. For auditory warnings, we considered simple and complex nonverbal signals, voice presentation, salience, and omnidirectionality, plus the problems of annoyance and false alarms. Other issues discussed included the use of multi-modal warnings (including visual and auditory presentation together, as well as other modalities), overload, habituation, interactive warnings, standardization, stimulus relevance, target population characteristics, influence by other stages of processing, and test methodology. Because attention to warnings is a function of many factors, we offer a general set of recommendations or guidelines below. The guidelines cannot be followed in every case, because in some situations they may conflict with each other and in others they may involve practical constraints.

To maximize the attention capture and maintenance, visual warnings should:

- Accentuate figure–background contrast
- Be brief
- Use large, legible print
- Include features that add prominence such as a signal word panel containing a signal word, color, and an alert symbol
- Include a pictorial symbol when possible
- Present information by way of multiple features and modalities to serve as redundant cues
- Make the formatting attractive, for example, use an outline or list format with spaces and bullets separating the main points instead of continuous, paragraph-type prose
- Be durable to endure the life of the product or hazardous condition
- Make better use of the available space on products/containers for warnings (to make the print larger or to include more information). Consider using methods that can enlarge the space for warnings. If this is not possible, refer users to another accessible source for more information
- Be located when and where the information is needed.

To maximize attention capture and maintenance, auditory warnings should:

- Be brief
- Have a high signal-to-noise ratio, but not be so loud that it badly annoys people
- Be clear and distinguishable from other sounds
- Have low false alarm rates
- Allow adjustments in detection sensitivity.

The warning development procedures should:

- Consider the sensory capabilities of the target population
- Consider the tasks and the environment in which the warning will be located
- Test a representative sample of target users.

We also recommend that, after a warning is placed into service, follow-up assessments be conducted of the warning's attentional effects. The purpose is to determine whether the warning is meeting the goals of attention capture and maintenance. If it is not working as intended, or its effectiveness has degraded over time, etc., the warning should be replaced with a better one.

By incorporating the above characteristics (and other recommendations suggested in this chapter), a warning is more likely to be successful in attracting and maintaining attention. In doing so, it paves the way for additional processing described in the next set of chapters.

We close this chapter by making a final comment. Today's increasingly sophisticated desktop publishing systems allow considerable freedom and flexibility in constructing warnings. Producers of signs and labels are free from simple typewriters that could produce only one size of type and a limited number of embellishments (i.e., all capital letters or underlining). Today's warning designers have access to word processing, graphic image processing, page layout, and document management software. Recently, some specialized sign- and label-making programs have become available. Thus, current desktop publishing capabilities make it easy to produce warnings. Similarly, computer-based sound processors can aid in the design of appropriate verbal and nonverbal auditory warnings by allowing the manipulation of loudness, frequency and complexity, rate, etc. Today's technology allows anybody with a modern computer and a color printer to construct warnings. However, it is important that warnings designers consider in their designs the factors discussed in this and other chapters.

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