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ATTENTION SWITCH AND MAINTENANCE

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ABSTRACT

This chapter describes the two major process stages of attention. The first involves switching attention to a salient stimulus. The second involves maintaining attention—while information is encoded in memory. This chapter focuses on factors that affect both stages with respect to visual and auditory warnings. Examples are provided and recommendations for future research are given.

INTRODUCTION

Most situations require that people divide their attention among various stimuli and events. According to most modern theories of attention, people have a limited capacity of attention or mental resources to be used for active processing (e.g., Baddeley, 1986). In most cases, we cannot attend to everything around us—we are selective, sometimes focused. Although we are capable of dividing attention to more than one thing, there is a limit to how much we can distribute attention. This limit is partly due to built-in capacity restrictions of people's information processing system and environmental context.

In general, we tend to look at, listen to, or think about the most salient or conspicuous aspects of our external world or to internal, ongoing processing of knowledge in the head. Conspicuity refers to the ability of a stimulus to standout from its background. Other terms that are used synonymously are prominence and salience. Of course stimuli differ in the extent that they are salient. Certain features or characteristics may facilitate salience, but, to some extent, the degree of salience depends on the individual's past history. Attention is generally given to the most conspicuous stimuli, and concurrent to the maintenance process, memories of that stimuli are produced (i.e., knowledge or memory structure). As a memory is formed, the stimulus becomes relatively less salient, and other stimuli or thoughts become relatively more salient. When salience diminishes for one stimulus, attention may then switch to a more conspicuous stimulus. In other words, there is a continuous process of focusing attention on one stimulus and then as it becomes known (memory structure is formed), attention switches to the currently most-salient stimulus or thought. Of course, actual processing is not as simple as this, but these basic notions will serve well to guide our discussion of the factors that influence attention with respect to warnings. We will return to this basic model of attention to discuss more about internal processes involved in attention switch and maintenance. Examples and future directions of research will be given.

ATTENTION STAGES AND WARNING MODALITIES

Stages of Attention

The two stages of attention are critical in the success of a warning. In the first stage, an effective well-designed warning attracts attention toward it. Prior to this point, attention was focused elsewhere. The effective warning stimulus draws attention away from other stimuli and thoughts. This is the switch stage. To

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cause this switch, the warning needs to be relatively more conspicuous than other things (e.g., stimuii, current thoughts).

The second stage of attention is maintenance. It occurs after the switch stage, whereupon attention is held to a stimulus while pertinent information is extracted from the warning and forms a memory (e.g., while a person reads text or examines a symbol or listens to a voice). To expedite information extraction, warnings should have certain characteristics such as being legible (if a visual warning) or intelligible (if an auditory warning) and having content that readily comports to existing memory.

Modalities

Most warnings are transmitted visually (e.g., signs and labels) or audibly (e.g., tones and speech). Visual warnings are provided in a variety of media including printed labels, posters, Web sites, and signs or in brochures, inserts, and product manuals. Some visual warnings are also presented electronically in the form of simple on/off lights, gauges, video displays, and so forth. Some auditory warnings are presented as simple tones and chimes, whereas others are presented as complex verbal instructions. Most of this chapter focuses on warnings in these two modalities.

However, it should be noted that hazard information might also be conveyed by other sensory modalities. For example, an odor is added to natural gas as an olfactory cue to detect leaks. A bitter taste may be added to household chemicals as a gustatory cue to elicit expulsion of toxic substances. Rumble strips stimulate the tactile/kinesthetic senses to alert drivers to road boundaries. These applications show that other sensory modalities may be useful in conveying hazard information in certain circumstances. Use of more than one sense is especially relevant to individuals who have limited visual and auditory capabilities or when attention is tied up in one sense. We will return to multiple sensory cues at a later point in this chapter. For further information on use of the other senses in warnings, see chapter 9 by Cohen, Cohen, Mendat and Wogolter (this volume).

The visual and auditory sensory modalities have somewhat different information processing characteristics. Although there are similarities between the two, certain features that are characteristic of one sense are not applicable to the other. Because of this, vision and audition are discussed separately in the attention switch and maintenance sections.

ATTENTION SWITCH

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

In this section, factors that influence the switching of attention to a warning are described. Most of the factors concern perceptual enhancements to increase warning salience and, thus, facilitate its ability to elicit a switch of attention to it. Deficiencies in perceptual characteristics can result in a failure to attract attention. Aspects relevant to visual warnings are given first followed by those relevant to auditory warnings.

Vision

Size. Larger objects tend to be more salient and are more likely to capture attention than smaller objects. On the roadways of the U.S. interstate highway systems, posted signs are massive structures to ensure that drivers will be able to detect and read the message at a distance to provide enough time to react to the message if necessary. Obviously, we cannot have billboard-size warnings everywhere, but the point is that warnings with greater size within existing constraints is generally desirable.

Brightness and Color Contrast. Whether we see an object depends on the figure-ground relationship (i.e., the object against its background). In a good figure-ground relationship, the figure or object is readily discernible from the background. With respect to warnings, the relationship can be between the warning and the environment in which the warning appears, or it can be between the component parts of the warning (e.g., letters or symbols) and their background in the warning. Figure-ground discernability is closely tied to brightness and color contrast.

Brightness contrast is a function of reflectance ratios of the figure and ground. High brightness contrast maximizes the light and dark differences of the object against its background. An example of good brightness contrast is black print on a white background (or vice versa). Examples of poor brightness contrast are gray print on a background of a similar shade of gray. Likewise, black print on dark gray has minimal brightness contrast. Research shows that features with greater brightness contrast are detected and localized faster than those of lower contrast (e.g., Brown, 1991; Sanders & 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 for the figure and ground.

Brightness contrast can be determined using the following equation (Sanders & McCormick, 1993):

$$C = (B_o - B_b)/B_b$$

Where C is the brightness contrast of the object against its background; B_o is the luminance of the object; and B_b is the luminance of the background. Luminance is defined as the amount of light reflected from a surface that reaches the human eye. In short, the greater the difference in light reflection of the figure and the ground, the better the contrast.

Color is one of the most important features that can help a warning stand out in most environments. It is one of the earliest processed pieces of information about stimuli. Red, orange, and yellow are commonly used in warnings. But the effectiveness of color in assisting warning detectability depends on whether there is sufficient contrast with its surroundings. Certain color combinations produce contrast that is nearly as good as black with 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.

Fluorescent color pigments are increasingly being used in warning applications. Fluorescent colors interact with ultraviolet light making them appear brighter than nonfluorescent colors. Fluorescent orange is used in many localities for roadwork signs, whereas strong yellow/green has been used for pedestrian-crossing signs. These colors provide good color contrast in many environmental settings and appear to be useful warning applications (Dutt, Hummer, & Clark, 1998; Zwahlen & Schnell, 1998). Research suggests that fluorescent colors offer the benefit of giving emphasis to warnings (Tomkinson & Stammers, 2000; Wogalter, Magurno, Dietrich, & Scott, 1999). However, not all hues are available as a fluorescent. Unfortunately, one of the most important colors for warnings, red, is not rendered well as a flourescent and appears pink.

Concern with brightness and color contrast should not be limited to the warning itself, but consideration should also be given to the predominant colors in the environment that will surround the warning. For example, in a largely orange environment or context (e.g., the walls of a building, or label of a product container), a orange warning will be less noticeable than other colors (Young, 1991). In that case, yellow or red would be appropriate for the sake of noticeability. In such cases, fullest advantage should be taken of color contrast to distinguish a warning from other objects and information in the environment.

Highlighting. Research indicates that when warning text is embedded in other text, use of some form of highlighting helps the warning stand out. It is a form of contrast. Usually highlighting is with color (changing the color of the letters or the background) or it might be using other methods such as a font change (e.g., bold print, all caps) that is different than the remaining text. Strawbridge (1986) found that participants using a glue product were more likely to notice an embedded warning when it was highlighted. Young and Wogalter (1990) found the 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. Of course, too much highlighting across multiple statements within a large section of text reduces the effect of consistently drawing attention to particular points in that text.

Illumination and Glare. Lighting conditions can adversely affect warning detection because of reduced contrast. One common problem is low illumination. With lower levels of light, warnings become less visible and, therefore, less detectable. Solutions include adding an artificial light source directed on the warning or by providing back lighting (as with public stairway exit signs). Another strategy is to make maximum use of the light that exists by using retroreflective materials as is commonly used in traffic signs.

Too much light can also impair contrast in the form of glare. Disability or veiling glare is defined as the introduction of a light source much brighter than the surrounding area making it difficult to see dimmer objects (Brown, Bookwalter, & Guenther, 1985). Disability glare can occur in two ways. One is when light reflects off a warning surface into the eyes and diminishes the contrast between the components and their background. The other cause is when direct intense light from a nonwarning source, such as oncoming headlights, the sun, (cf. Dahlstedt & Svenson, 1977), or other kinds of very bright light is directed at the viewer's line of vision.

Other glare sources can create discomfort within the viewer. Discomfort glare can affect the ability of a warning to capture attention because people avoid looking in the direction of the glare source and thereby not seeing a warning that is also placed in that direction. In Wogalter, Kalsher, & Racicot (1993a) a warning sign with an attached high-intensity strobe light was less effective than a sign without the flashing light, apparently because it was uncomfortable to look in that direction.

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. For example, roadway lane markings can become difficult to see while driving east at dawn or west at sunset because of sun glare or on dark wet roadways with glare sources from oncoming headlights.

Environmental Conditions and Exposure. Other environmental conditions can have effects similar to low illumination. They include the presence of smoke, fog, rain, and condensation (see e.g., Lerner & Collins, 1983).

Durability. Over time and exposure to environmental elements, warnings can dull in appearance and become less noticeable. Exposure to sunlight may cause the ink pigments to fade. Also, exposure to other environmental elements such as air pollution, dirt, grime, water, cold, and heat can cause degradation from its original printed state (Dorris & Davis, 2003). Also, ink colors degrade at different rates. Furthermore, rusting, scratches, and discoloration can occur over time resulting in a less conspicuous warning. Dorris and Davis suggested that the deterioration of forest-harvesting equipment warnings would likely lead to large reductions in noticeability. See Glasscock and Dorris (chap. 39, this volume) for a discussion of issues associated with warning durability.

Context. The context in which the warning appears can affect noticability. One example is size—generally, larger is better. However, it is not just the size of the warning itself that matters, but also the overall available display space and how much space is allocated to other information in the display. Similarly, a statement in large bold print is less likely to be selected for attention when there is other information in the surrounding environment in even larger bolder font.

Other stimuli in the environment or on a product label can compete with the warning for attention capture. The presence of other persons, various objects that compose the context, as well as tasks that the person is performing can distract the individual from the warning's presence. When distraction by other salient stimuli is likely, the warning needs to be particularly conspicuous to enhance the likelihood it will be seen. Another way to handle this same problem is to decrease the clutter so that distraction likelihood is reduced (Wogalter, Kalsher, & Racicot, 1993).

Borders. Placing a border around important safety information is another way to make a warning stand out from (or contrast with) its background by enhancing its figure-ground relationship (e.g., Ells, Dewar, & Milloy, 1980; Rodriguez, 1991). For example, Rashid and Wogalter (1997) found that certain border conditions (e.g., having thick, colored diagonal stripes) were rated more attention getting than other border conditions (e.g., no border or a thin black line border). Wogalter and Rashid (1998) also measured pedestrians' looking behavior in which the presence and type of border around a posted warning was manipulated and placed at a high-volume pedestrian area. Their results confirmed earlier rating studies. A thick colored border around the sign increased the number of people directing their gaze to the sign compared to signs with a thin or no border. A positive effect of a thick border around the signal word portion was also found by Adams and Edworthy (1995).

However, the presence of a border has not always yielded positive results. Laughery, Young, Vaubel, and Brelsford (1993) did not find a positive effect for a thin, rectangular border around a warning in a reaction time search task. Also, Swiernega, Boff, and Donovan (1991) observed that the presence of a border slowed performance in a rapid recognition task. The reduced performance in Swiernega et al. might be attributable to a perceptual effect called lateral masking in which nearby markings (in this case, that composing the borders) obscures or blurs with nearby features (Averbach & Coriell, 1961). Overall, it appears that a thick border may be useful for attention attraction with the use of white spacing to separate the border from the textual portion of the warning. Thin borders may not be better than no border, except for separating sections of the warning from other material.

Signal Word Panel. The American National Standards Institute (ANSI, 2002) Z535 standard on sign and label warnings recommends that warnings contain a rectangular signal word panel on the uppermost portion of the display. 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) that together comprise a multiple-feature configuration (e.g., FMC Corporation, 1985; Westinghouse Electric Corporation, 1981; Wogalter, Kalsher, Frederick, Magurno, & Brewster, 1998). Examples are shown in Fig. 18.1.

FIGURE 18.1. Three examples of ANSI Z535.2 formatted warning signs. Reproduced with permission from Electromark (http://www.electromark.com/). (See Color Plate 7).

Although there has been considerable research on the panel's components, individually and in combination, most of it has concerned the degree or level of hazard that they connote (Chapanis, 1994; Kalsher, Wogalter, Brewster, & Spunar, 1995; Wogalter, Kalsher et al., 1998; Wogalter, Magurno, Carter, Swindell, Vigilante, & Daurity, 1995). Several studies (Kalsher, et al., 1995; Silver & Wogalter, 1989; Young, 1991) have used ratings of noticeability. These studies suggest that warnings with the components of the ANSI signal word panel tend to receive higher subjective ratings of noticeability than warnings without those components. There have also been a few studies that have used objective performance measures. Laughery et al. (1993), using reaction time and eye movement measures, found that an alcohol warning printed in red with a signal icon was detected significantly faster than a black warning without a signal icon.

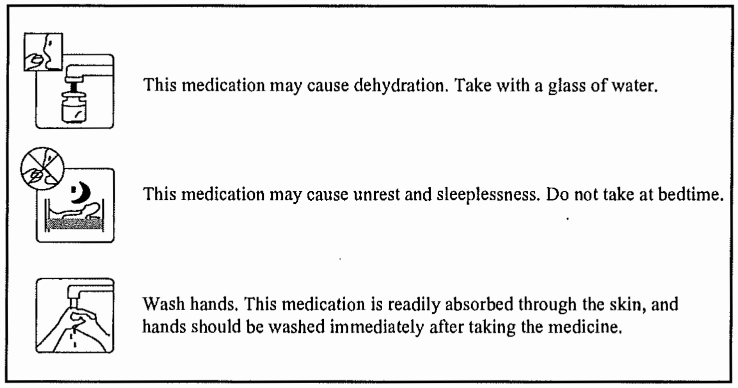

FIGURE 18.2. Warning text accompanied by symbols. Pictograms reproduced with permission from United States Pharmacopeial Convention Inc. (http://www.usp.org/).

Similarly, Braun, Greeno, and Silver (1998) found that warnings printed in red are more likely to be complied with than warnings printed in black or green. Bzostek and Wogalter (1999), using pharmaceutical labels, found that warning detection was significantly faster when it contained a signal word in color (that distinguished it from other text) and/or contained one of several icons.

Symbols. Many warnings employ symbols, also called pictorials, pictograms, and icons. One example is the alert symbol—an exclamation point within a triangle—that is part of the ANSI Z535 signal word panel. Most of the research on pictorial symbols and icons concerns their comprehension. However, a frequently overlooked benefit of symbols is that they also attract attention. This characteristic stems from the relative salience and prominence of graphics compared to text. In part, symbols tend to be relatively larger than the textual components, and they tend to be more unique in shape compared to ubiquitous text.

Research shows that warnings with symbols are rated more noticeable (e.g., Kalsher, Wogalter, & Racicot, 1996; Sojourner & Wogalter, 1998) than warnings without them. Figure 18.2 depicts several medication-related warnings accompanied by symbols used in Sojourner and Wogalter (1997) who found that warnings with symbols and text are rated more noticeable than warnings with text only. There is also research with performance measures that supports their attention attractiveness. Research using objective reaction time measures showed that a warning that includes an icon is easier to detect in reaction time experiments (Bzostek & Wogalter, 1999; Laughery et al., 1993).

The attention-getting benefit of symbols is manifested regardless of their understandability. For some complex, abstract concepts it may be very difficult to develop a symbol in which comprehension is high without specific training with its referent language label. Nevertheless, sometimes the inclusion of a symbol that does not meet conventional levels of comprehension (85% correct) might still be warranted if it can help serve the attention switch function. This assumes that it is not likely that a symbol with a higher comprehension rate can be developed, and there are very few errors of comprehension that could lead to unsafe behavior, that is, a low critical-confusion error rate. Other chapters in this Handbook discuss more about symbol comprehension tests (see Deppa, chap. 37; Johnson, chap. 36; Peckham, chap. 36; Wogalter, Silver, Leonord, & Zaikina, chap. 12, this volume).

Location. Placement of the warning is critical for its noticeability. A warning that is not seen has little or no effectiveness (with the exception of indirect effects). In general, warnings should be located where people will be expected to look so that they are more likely to be noticed (Cole & Hughes, 1984). One general guideline is that most people's relaxed looking angle for straight-ahead viewing is between 15 to 35 degrees below horizontal. The process of determining the best location(s) may require a task analysis (e.g., Frantz & Rhoades, 1993; Lehto, 1991). A task analysis can be used to break down work tasks into cognitive and motor units so that they can be analyzed to determine the locations where people tend to focus their attention as they perform the work. See Frantz, Rhoades, and Lehto (1999) and Frantz and Rhoades (1993) for a more detailed discussion on task analysis.

In general, a warning's attention-getting power will be facilitated by placing it close (or proximate) in time and space to the hazard. Thus, in most cases warning noticeability will be benefitted by its attachment directly to the product (or its container) as opposed to a more distant placement such as in a separate instruction manual (Frantz & Rhoades, 1993; Racicot & Wogalter, 1995; Wogalter, Barlow, & Murphy, 1995; Wogalter et al., 1987). For example, a warning about carbon monoxide poisoning on a gas-powered electrical generator is more likely to be noticed at the proper time than a warning in the product manual (Wogalter, Kalsher, Glover, & Magurno, 1999).

Although proximal placement is a reasonably good rule to follow, in certain circumstances a warning placed too close to the hazard can be ineffective and sometimes dangerous. A work zone that has no other signs than a single one placed at the work zone itself would be insufficient if people need to make avoidance maneuvers before reaching the work zone. A better placement would provide sufficient advance notice about the upcoming hazard to provide enough time and space to avoid it. However, the warning should not be too distantly placed from a hazard as it might be forgotten in the intermediate time. For example, a verbal warning given to a farm worker who a week later starts using a hazardous pesticide is less likely to be remembered, and therefore, less effective than one given immediately prior to using the product.

Location of important safety information on Web sites has also been shown to affect the likelihood that the information is seen and read. Vigilante and Wogalter (2005) found the risk information placed lower in a Web site's hierarchy or below the page scroll of a Web site's home page is not likely to be seen. Rather, it is better to place the risk information in the top half of the home page or provide a conspicuous link to the information.

Sometimes warnings cannot be placed at optimal locations, and a place has to be made. Figure 18.3 shows a traffic sign for which the pole is angled to get it off of the street and pedestrian walkway. A straight pole would be hazardous.

For some products and environments, aesthetics sometimes need to be considered, particularly if it is a low-severity hazard. For example, people may not like having a highly conspicuous warning displayed on the front panel of a stereo receiver regarding hazardous noise levels, even though the warning would be quite prominent at this location. However, people believe that warnings should be attached directly to highly hazardous products (Wogalter, Brelsford, Desaulniers, & Laughery, 1991). Construction equipment that generates very high sound levels for long durations probably would not suffer an aesthetics problem with a relatively prominent warning for permanent hearing loss.

Another common location for warnings is in the product manual. This is one of the least preferred locations with respect to noticeability because product manuals are sometimes not available, and even if they are, they may not be read (Mehlenbacher, Wogalter, & Laughery, 2002; Wogalter, Vigilante, & Baneth, 1998). Even if the manuals are opened, the warnings in them might be missed, because they are frequently embedded within other information. Because of this, the most important information should be attached to the product or its container (Wogalter et al., 1991).

Nevertheless, poor placements can be compensated for (somewhat) when used in conjunction with a prominent well-located brief warning that directs the user to look for more detailed information at another accessible location (Wogalter, Barlow & Murphy, 1995). 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) would increase the likelihood that one of the warnings is seen.

Repeated Exposure. Repeated and long-term exposure to a warning may result in a loss of its ability to attract attention. This process is called habituation (Wogalter & Brelsford, 1994). Changing the warning's appearance should help to reduce habituation (Leonard, Otani, & Wogalter, 1999; Thorley, Hellier, & Edworthy, 2002).

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. The continued presence of an indicator light increases the likelihood that individuals will detect it, but it does not ensure detection (e.g., seatbelt warning light on a dashboard). Flashing lights attract attention better than continuous indicator-type lights. For example, some traffic signals incorporate a flashing light into the red phase to help capture the drivers' attention to the signal's presence.

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 (starting at approximately 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 so that an operator will not miss the light when glancing at a display panel during its off time.

Implications. Warning conspicuity is particularly important because people are often focused on other aspect of the world, such as performing tasks or considering other things of interest (Weegles & Kanis, 2000). Thus, it is necessary for warnings to be conspicuous and stand out against competing distractions to capture the intended viewer's attention. In the preceding section factors that can influence the noticeability of visual warnings in the attention switch stage were described. How auditory warnings are involved in attention-switch processing is discussed next.

Audition

Any sound stimulus, whether simple or complex, can alert and attract attention unless it is masked by another sound. Auditory warnings are commonly used to alert people to various hazards. Even the simplest sounds such as sirens, tones, buzzers, bells, and whistles can produce an alerting reaction and sometimes an overt startle response. Sounds like these are a powerful way to get people's attention. Good warning alerts will attract people from other tasks on which they are focused. This alerting value gives auditory warnings a desirable characteristic for attracting attention. Several chapters in this handbook address more specific details of auditory warnings (Bliss & Fallon, chap. 17; Edworthy & Hellier, chap. 15; Haas & Edworthy, chap. 14; Meyer, chap. 16; this volume).

Sound Localization. Another major advantage of an auditory warning is its omnidirectional nature (Wogalter, Kalsher, & Racicot, 1993; Wogalter & Young, 1991). 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 do not need to be looking at a specific location to be alerted. In most cases, the ears are always available to receive sound, unlike the eyes, which might not be in position to receive a visual warning.

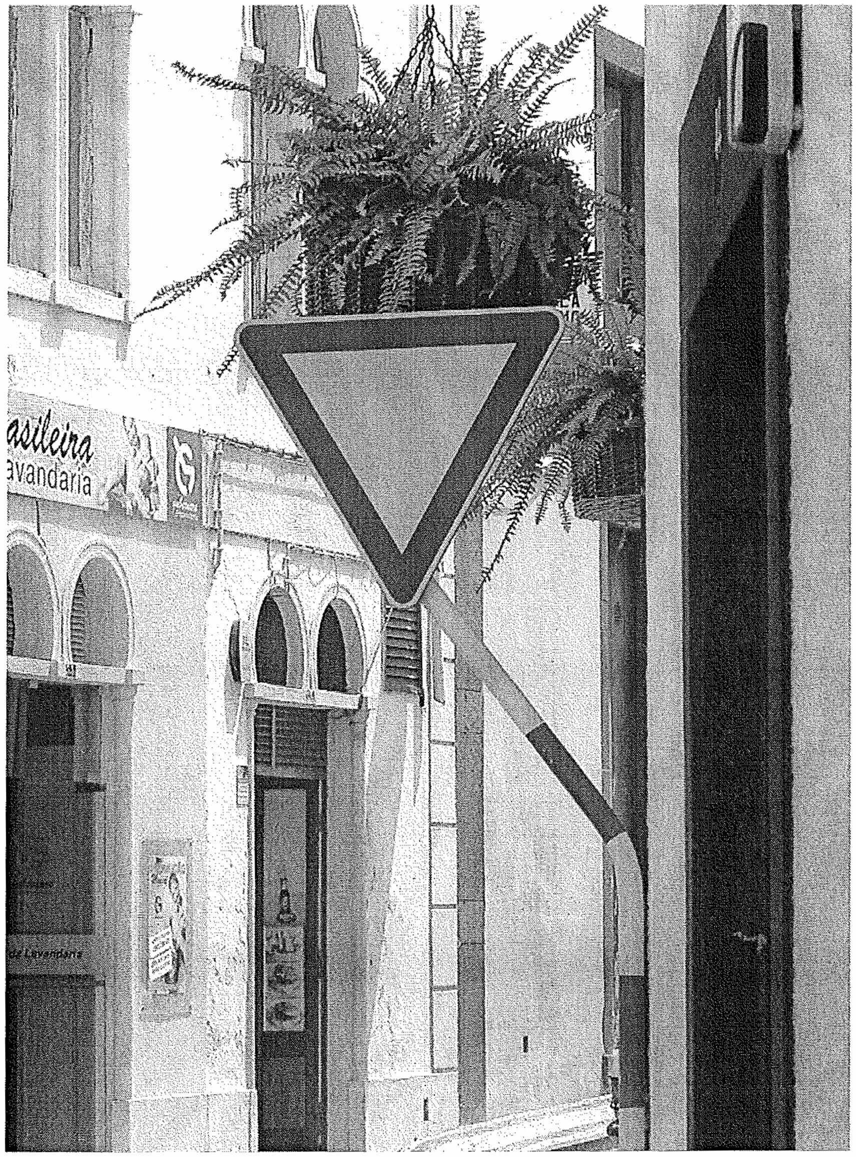

FIGURE 18.3. Sign with bent pole is from Lisbon, Portugal. (See Color Plate 5).

Although sound waves diverge, they can also provide directional cues. Generally, people can determine the location of mid- to high-frequency sounds that arrive directly at their ears. This localization is made possible by small differences in the time and intensity of the sounds arriving at the two ears. This directionality or localization of auditory cues can be potentially useful for visual warnings. An alert on a control panel can cue the operator to attend to a visual display so that the specific reason for the auditory signal can be determined (Eastman Kodak Company, 1983; Sanders & McCormick, 1993; Sorkin, 1987). An alert from a small auditory speaker mounted on a warning sign can cue the receiver to look in the direction of the sign (Wogalter, Kalsher, & Racicot, 1993).

Sensitivity. The human auditory system is more sensitive to some sounds than to others. For example, the human voice is transmitted at frequencies for which our auditory system is most sensitive (approximately 800 to 5000 Hz; Coren & Ward, 1989). In general, auditory warnings should be given at these frequencies. However, there are other considerations. The warning signal could interfere with the reception of relevant verbal discourse in an emergency situation that might also contain hazard information. In addition, there might be other sounds at these frequencies (e.g., in a noisy factory) that might mask or obscure the warning sound. Thus, an auditory alert signal should contain tonal qualities different from those comprising expected other noises in the environment. Although the warning(s) should be different from other sounds, it should still be within the sensitive regions of human hearing.

Interference. The previous discussion indicates the importance of considering interference in the design of auditory warnings. Three kinds of interference are relevant. One was mentioned earlier—masking caused by other noise that covers or obscures the warning sound. The background noise may vary in loudness, frequency, and complexity. Some examples are loud machinery in an industrial environment or loud music while driving an automobile.

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 sounds and to prevent hearing loss. Vehicles with closed windows are another example where sounds outside the vehicles, including sirens from emergency vehicles, are attenuated. Thus, auditory warnings should be designed to be distinctive from the expected background noise and are not easily shielded. One potential solution is to include microphonic/electronic headphone speakers in ear muffs that allow certain sound frequencies to get through over and above the masked or attenuated extraneous noises. Another possible solution includes electronics in vehicles and other enclosed spaces that are capable of registering predetermined signals indicating an emergency that then transmits information within the shielded environment through a speaker system. These devices can be chosen so that the warning frequency is not attenuated by the hearing protection. Thus, it is important to determine how other expected background sounds might affect the signaling ability of an auditory warning. Of course, better solutions include decreasing the extraneous noise at the source or along the path if possible. For example, engine mufflers on construction equipment could be used to lower the total noise. Also in-vehicle entertainment systems could be tuned to pick up signals from emergency vehicles and then lower the sound level of the entertainment system.

A third type of interference concerns the warning itself. The alert may distract important mental processing of the receiver. That is, the considerable alerting value that makes auditory warnings useful for capturing attention can also be a hindrance when they distract receivers from a critical task (such as attempting to correct the problem the warning is signaling). For example, 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. Furthermore, very loud sounds can cause threshold shifts that can cause temporary or permanent reduction in one's ability to detect subsequent sounds (Kryter, Ward, Miller, & Eldredge, 1966; Ward, Glorig, & Sklar, 1958).

Numerous foreseeable background and signal conditions should be evaluated when designing an auditory warning system to attract attention. However, as a general rule of thumb, to attract attention, auditory warnings should be:

- Presented at frequencies for which the human ear is sensitive.
- Louder and spectrally different from the expected background noise.
- Not be so loud that they distract the listener from performing important tasks.

Implications. Auditory warnings tend to be naturally noticeable because of their omnidirectionality where the receiver does not have to be oriented to a particular direction (unlike with visual warnings). However, the warning might not be noticed if the presentation is masked by other sounds. Auditory alerts can orient people to look for visual cues (e.g., a printed warning). Care in the design of auditory warnings is needed. They should be made distinctive from anticipated background noise and not blocked by shielding or hearing protection, and they should not be so annoying and intrusive that they interfere with important safety-related tasks.

ATTENTION MAINTENANCE

Individuals may notice a warning but not stop to examine it further. A warning that is noticed but fails to maintain attention long enough to extract its content is of little direct value. Once attention has been attracted to the warning, it is important that the warning hold attention so that information can be encoded (see also Hancock, Bowles, Rogers, & Fisk, chap. 19, this volume; Rousseau, Lamson, & Rogers, 1998; Wogalter & Leonard, 1999). When the text of a warning is read and or a symbol is examined, at least some of the information is assimilated into existing memory (i.e., encoding) forming knowledge. During this process, the warning should have qualities or features that avoid attention from being easily distracted by and to other stimuli before the encoding process is completed.

With brief warnings the message information can be acquired very quickly, sometimes as fast as a glance. For longer and more complex warnings, in order to maintain attention, they need to possess qualities that generate interest and do not require excessive effort. Some of the same design features that facilitate the switching of attention also help to maintain attention (Barlow & Wogalter, 1991; Wogalter, Forbes, & Barlow, 1993). For example, large print not only attracts attention, but also increases legibility, thus making the reading process less effortful with a greater likelihood that attention will be maintained.

In the following sections, visual and auditory factors involved in attention maintenance are discussed.

Vision

Legibility. An important factor for maintaining attention to a visual warning is legibility. Legibility refers to how well the separate features that make up an object (letter characters or symbols) can be distinguished so that the object can be identified and recognized. If individuals have difficulty discerning the letters of words or the components of a symbol, they are less likely to expend the time and energy necessary to decipher them. Therefore, the warning will fail to maintain their attention.

Sometimes legibility is confused with readability. Both are concerned with ease of reading. However, readability concerns larger groups of text (e.g., words, sentences) in which comprehension of the content of the material is its main constituent (Leonard et al., 1999). Legibility concerns the manifest ways that the text looks and whether the individual characters and their features are discernable. Legibility is a function of numerous variables such as type of font, its size, its density, and so forth. Recommendations include using larger size, familiar (frequently used) fonts that are not densely compacted so that the individual letters and words can be distinguished as separable. In the next several sections, some of the major aspects of legibility are described, but also see Frascara (chap. 29, this volume) for more information on legibility.

Size and Visual Angle. Legibility is frequently associated with size, or more specifically with respect to text, letter height. Underlying the size dimension is visual angle (Smith, 1984). Visual angle refers to the area occupied on the retina by the feature's image. With a small retinal image, fewer cone receptors register the individual components, resulting in poorer visual acuity. If the visual angle is very small, the viewer may not see elements as separate and distinguishable, but rather may see them blurred together. The size of a visual angle is a function of both actual size of the stimulus and its distance away from the eye. At greater distances, a given stimulus produces a smaller visual angle to the observer than if it or the observer were closer.

The general population is comprised of people with visual deficiencies. For example, older adults as a group have age-related visual declines (Rogers, Lamson, & Rousseau, 2000; Rousseau et al., 1998) and are more comfortable with and prefer larger type sizes than younger adults (Vanderplas & Vanderplas, 1980; Wogalter & Vigilante, 2003; Zuccollo & Liddell, 1985). Even with appropriate vision correction (e.g., eyeglasses), warnings with very small print may not be legible. Figure 18.4 shows an example of a medication label with small print and poor legibility as used in Vigilante and Wogalter in comparing labels with

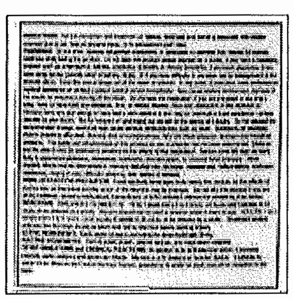

FIGURE 18.4. An example of poor legibility due to small print.

different print sizes and formats. Younger adults were able to read this label (when shown in 4 pt. type), but older adults could not. See Mayhorn and Podony (chap. 26, this volume) for more on warnings and the older-adult population, and Smith-Jackson (chap. 24, this volume) on receiver characteristics. Thus, in choosing type size, consideration should be given to the expected user population.

Although persons with good visual acuity (e.g., younger adults) may be able to read small print, they may not do so. It is more effortful to read poorly formatted print, and they may also believe that print so small is relatively unimportant (Wogalter, Forbes & Barlow, 1993; Silver & Braun, 1993; Wogalter & Vigilante, 2003; Young & Wogalter, 1990). Thus, for multiple reasons, larger print is preferred to smaller print. However, there is an upper limit to this rule. If the print is too large, it will be difficult to encompass the information at a glance. If consumers are expected to hold a product in their hands while using it, then one general guideline is to use font sizes that can be read at that distance. However, the letter heights for a "Keep Out" sign at an electrical utility power station should be calculated based on the distance from the sign to the peripheral approaches to the site. As guidance, ANSI (2002) Z535.2 and Z535.4 provide a chart of print size and expected reading distances in good and degraded conditions for environmental safety signs and product labels, respectively.

Although visual angles are based on letter height, there is more to recognizing characters than their vertical size. Other factors include the particular font used, stroke width, leading, letter compression, height-to-width ratio, distance between letters, case, resolution, and justification. See Frascara (chap. 29, this volume), Sanders and McCormick (1993), and Tinker (1963) for more information on these and other typographical characteristics.

Letter Case. Warnings are sometimes printed in all uppercase (capital) letters. Given the same point size, uppercase letters are physically larger than lowercase letters. Because of their generally smaller size, lowercase letters produce smaller visual angles than the uppercase letters. By their size alone, uppercase letters might be assumed to be more legible than lowercase letters (Foster & Bruce, 1982). However, experts on typefaces have noted that mixed-case materials (both uppercase and lowercase) can be more legible than all uppercase materials (Tinker, 1963; Williams, 1994). Uppercase letters have a block-like appearance making them highly similar and confusable from one another under low-legibility conditions (e.g., small visual angle, low illumination). Lowercase letters are more unique in shape and are thereby more distinguishable than uppercase letters. Figure 18.5 depicts the government warning for alcoholic beverages on all alcoholic beverage containers sold in the United States (Wogalter & Young, 1998). One is all uppercase letters and the other is in mixed case. Although both versions take up the same amount of label space, the mixed-case version is more legible and readable.

Garvey, Pietrucha, and Meeker (1998) compared the font Clearview to a standard highway sign font. Clearview's lowercase letters were designed 12% larger than the standard font. They found that increasing the physical size of the lowercase

Government Warning: (1) Women should not drink alcoholic beverages during pregnancy because of the risk of birth defects. (2) Consumption of alcoholic beverages impairs your ability to drive a car or operate machinery, and may cause health problems.

GOVERNMENT WARNING: (1) WOMAN SHOULD NOT DRINK ALCOHOLIC BEVERAGES DURING PREGNANCY BECAUSE OF THE RISK OF BIRTH DEFECTS. (2) CONSUMPTION OF ALCOHOLIC BEVERAGES IMPAIRS YOUR ABILITY TO DRIVE A CAR OR OPERATE MACHINERY, AND MAY CAUSE HEALTH PROBLEMS.

FIGURE 18.5. Uppercase versus lowercase text (using the required warning text of the warning required on alcoholic beverage containers in the United States).

letters (while still being within the footprint space of standard font) produced better recognition and reaction time scores than the standard font.

Character Spacing. Research has shown that under certain conditions, closer spaced type enhances reading speed (Moriarity & Scheiner, 1984). When the print is legible, spacing characters closer together requires fewer eye movements to read longer words and, therefore, faster reading speeds. However, some spacing is needed so that the letters do not run into each other (Anderton & Cole, 1982; Watanabe, 1994; Young, Laughery, & Bell, 1992).

Font. Font style can affect legibility particularly when highly elaborate, unusual, unfamiliar fonts are used. The ANSI (2002) Z535 standards recommend sans serif fonts (without character embellishments) such as Helvetica, Arial, and Universe over fonts with serifs (with character embellishments) such as Times Roman, New Century Schoolbook, and Goudy. Serif fonts are considered preferred when the font size is small (as in many product labels and most manuals). Proofreaders report serif fonts to be less fatiguing than sans serif fonts. The presence or absence of serifs probably does not have a substantial effect assuming the font style is not extremely unusual or elaborate.

Symbols. As suggested earlier, the relevant features of symbols need to be legible. Too much detail can make a graphic illegible when it is reduced in size or viewed at a distance. Also, irrelevant detail can potentially attract viewers away from relevant parts of the symbol. Most design standards and guidelines recommend using large, bold components in safety symbols. However, large blobs of ink without much white space separating the components can also render a pictorial symbol illegible.

An often-used type of symbol for warnings is the circle–slash prohibition symbol. Some commonly used examples of symbols incorporating the circle–slash are shown in Fig. 18.6. However, it is important to note that the over-slash does not obscure the critical elements of the symbol that are necessary for its proper interpretation. For example, Dewar (1976) and Murray, Magurno, Glover, and Wogalter (1998) found that the slash could obscure critical features of symbols, decreasing recognition of their meaning. Murray et al. showed that simple adjustments such as reversing the symbol could aid identification performance (see also Wogalter, Murray, Glover, & Shaver, 2002).

Contrast and Environment. Low figure-ground contrast of the print and background can decrease the discernability of the individual/separate warning features, thus reducing legibility, ease of reading, and attention maintenance (e.g., Sumner, 1932). The print and background should be comprised of dark print on light background (or vice versa) or comprised of two highly distinguishable colors rather than two shades of gray or two colors with similar brightness contrast. Environmental conditions such as smoke, fog, a massive rain storm, reduced light, and so forth can also negatively affect legibility (e.g., Lerner & Collins, 1983; Wardell, 1987). One 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 most other hues do, which could be a problem if red is tied to a dark color as its foreground or background. Other safety colors, orange and yellow, can get washed out under certain kinds of artificial lighting.

Durability. As mentioned earlier with respect to attention switching and noticeability, warnings can degrade over time with exposure to sunlight, air pollution, dirt, grime, water, cold, and heat. The inks can degrade causing decreased color and

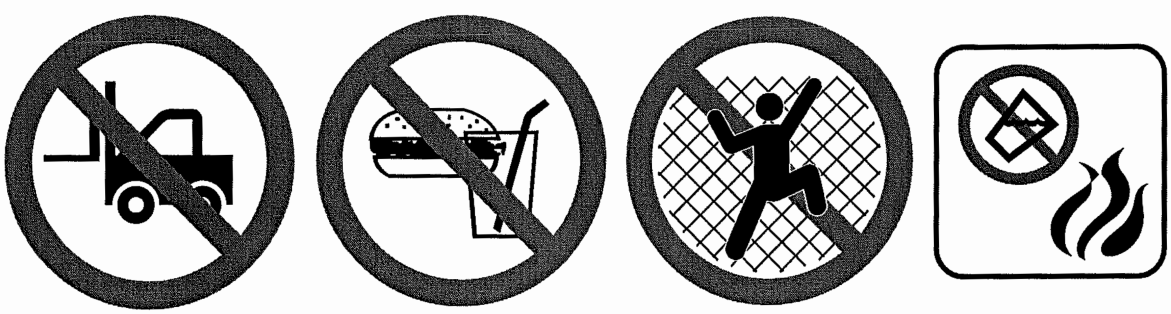

FIGURE 18.6. Four example symbols with circle–slash prohibition.

brightness contrast (Dorris & Davis, 2003). Also, colors may degrade at different rates. For example, red and magenta pigments tend to fade and discolor more quickly than other colors. Also, abrasions directly on the surface of the warning can cause deterioration (Dorris & Davis; see also Glasscock & Dorris, chap. 39, this volume).

Because the warning should remain in satisfactory condition over the expected existence of the hazard (ANSI, 2002), the environmental conditions under which a product label or a sign is expected to be exposed over time should be considered when choosing materials and the warning's location. Signs and labels expected to be exposed to degrading environmental elements should be maintained through periodic inspection and replaced when necessary.

Printing. Legibility can be adversely affected at the print production stage. For example, ink may spread or bleed across a wider area and fill in details that would otherwise help to distinguish the characters. A similar problem occurs for certain types of projected displays (e.g., on computer screens). For example, the stroke width of light letters on dark backgrounds generally needs to be somewhat smaller or thinner than its reverse, dark letters on a light background. The reason for this polarity difference is that the light forming the letters spreads out making the stroke width look wider than it is, a phenomenon called irradiation (Sanders & McCormick, 1993).

Limited Space. In some situations, there are constraints on space. Limited space is a particular problem for products with multiple hazards that are packaged in small containers. Providing a warning with all of the hazards would force the use of very small print, and, consequently, legibility would be reduced and fewer people could or would read it. Nevertheless, several alternative strategies could be considered in dealing with this limited space problem.

One alternative is to select certain information for emphasis (Young, Wogalter, Laughery, Magurno, & Lovvoll, 1995) and exclude less important information. The abbreviated warning label could refer users to a more complete set of information elsewhere (Wogalter, Barlow, & Murphy, 1995). This strategy may be acceptable if indeed that information is readily available. Access to manuals cannot always be guaranteed as some are thrown away or lost (Wogalter, Vigilante, & Baneth, 1998).

A second alternative is to increase the surface area available to allow for more information (or larger components) to be included. Several alternative methods for increasing label space on small glue and pharmaceutical containers have been proposed including a tag, wrap-around, fold-out, and cap label designs (Wogalter & Vigilante, 2003; Wogalter & Dietrich, 1995; Wogalter & Young, 1994). Research has shown that increasing the surface area of a label attached to a very small container results in greater preference for and compliance to an on-product warning compared to a conventional warning with smaller text (Barlow & Wogalter, 1991; Kalsher, Wogalter, & Racicot, 1996; Wogalter & Vigilante, 2003; Wogalter & Dietrich, 1995; Wogalter, Forbes, & Barlow, 1993; Wogalter & Young, 1994). Figure 18.7 shows a bottle container with an

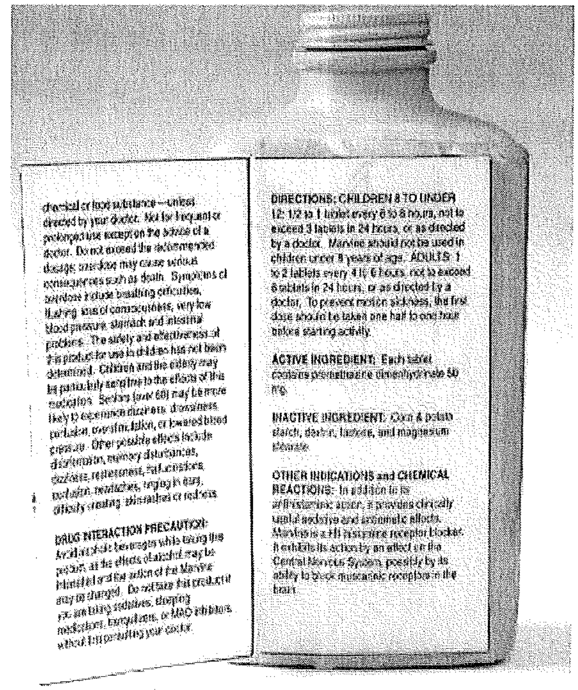

FIGURE 18.7. Supplemental label design to increase label space on a medication container.

extended-area design (Wogalter & Vigilante, 2003). Figure 18.8 shows a set of prototype warning label designs used in the research of Barlow and Wogalter (1991).

Formatting. The appearance of the warning can influence whether individuals will choose to maintain attention to the material or look elsewhere. People are more likely to look at aesthetic designs than designs that are unattractive and poorly formatted. If a warning contains a large amount of dense, compressed text, people may decide that it will take too much effort to read it and/or that it is probably not important because of the belief that if it was important then it would have been presented better. Given a poorly presented display, the individual is likely to switch his or her attention to something else more interesting.

One aspect of formatting is using white space between textual and graphical components. Prose text that is in single-spaced paragraph format with little white space is less likely to hold attention compared to text that is in an outline or list format with more white space. Not only does white space reduce the density of the text, but it can also show the conceptual organization of the material, making information acquisition easier. Research found that information presented in a list format results in faster reading, better comprehension and recall, greater preference, and better task performance than information presented in paragraph prose format (Desaulniers, 1987; Morrow,

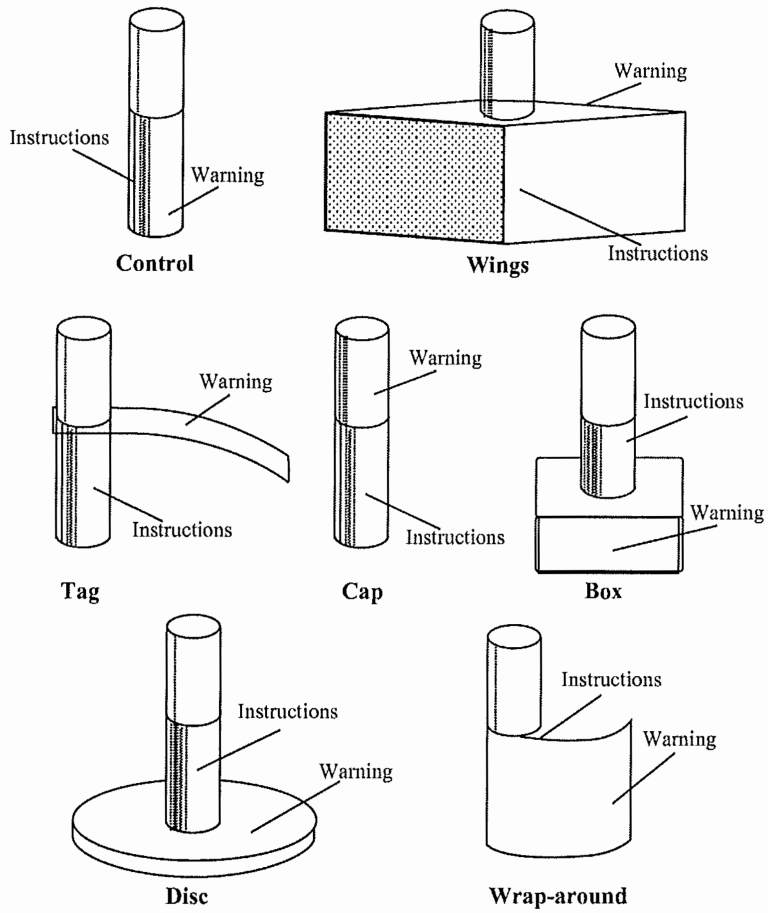

FIGURE 18.8. Prototype warning label designs used to increase label space on consumer products. Reprinted with permission from S. T. Barlow and M. S. Wogalter, *Interface 91: The Seventh Symposium on Human Factors and Industrial Design in Consumer Products*, 1991.

Leirer, Andrassy, Hier, & Menard, 1998; Wogalter & Post, 1989; Wogalter & Vigilante, 2003). Furthermore, research showed that simply increasing the vertical spacing between lines of text (i.e., leading) facilitated reading speed (Hartley, 1994, 1999). Other research showed that grouping text into separate, conceptually related sections can facilitate the search and acquisition of information (Tullis, 1997).

Another aspect of formatting is justification. Full justification may appear aesthetically pleasing because of the straight alignment of both margins, but it can slow reading speed because of the variable spacing between letters and words. Left justification (ragged right) is preferred where the horizontal spacing between the components is more consistent and predictable, aiding predictive saccadic eye movement. For more information on this topic, see Frascara (chap. 29, this volume).

Location. Warnings should be placed so that people can comfortably examine them. For example, a posted sign warning that is positioned at an angle, instead of straight on, can be more difficult to read and may discourage further looking. Most people tend to scan printed material left to right (except for persons using some languages such as Hebrew and Arabic that produce the reverse) and top to bottom. Thus, the most important hazard information should be located at or near these priority regions and not buried in the middle or bottom (Vigilante & Wogalter, 2005; Wogalter et al., 1987).

Integration or Separation From Instructions. Most products come with information on how to operate, maintain, and service the equipment, in addition to warnings about hazards. How warnings should be presented with respect to procedural instructions and other information has been the subject of guidelines by various groups. For example, the Environmental Protection Agency (1991) and other U.S. 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 presented separately 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. Wogalter, Kalsher, & Racicot (1993) found that a warning in a set of instructions was complied with more frequently than a (larger separated) sign warning. Frantz (1992, 1994) found greater warning compliance if the warnings were included within the instructions, as compared to separate sections of warnings and instructions. Additionally, Edworthy et al. (2004) found that professional users were more likely to comply with the warnings for a pesticide product when the warnings were presented within the directions, as compared to separate precautionary and statutory sections.

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 that the separate warning differed somewhat from the embedded version. In another study, Wogalter, Smith-Jackson, Mills, and Paine (2002) 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 (2002) Z535 guidelines produced higher knowledge scores in a comprehension test than either a more simply designed separated or integrated warning. Similarly, Vigilante and Wogalter (2005) found that drug risk information was found faster, in less clicks, and recalled more often when it was presented in a section separated from the drug's benefits.

As these descriptions indicate, research on integrated versus separated warnings has produced equivocal findings. Some of the different findings are probably due to familiarity with and complexity of the product or task, the perceived risk, or the information processing objectives of the user. Products and tasks perceived to be familiar, simple, and of low risk produce less concern by users than those perceived to be less familiar, complex, and high risk (Wright, Creighton & Threlfoll, 1982). In the former case, separate, highly conspicuous warnings placed at strategic locations might be better than integrated ones. In the less familiar case, people are more likely to go through the instructions step-by-step, and so it is probably better to integrate the warnings with the operating instructions. Furthermore, people who are searching for specific types of information are more likely to find it if it is presented in a separate, distinct section; whereas people who are attempting to perform a task may be more likely to read warnings integrated with instructions.

Implications. Warning legibility allows people to carry out encoding processes after the warning is noticed. If the warning is not legible, then people will likely not maintain their attention to the warning and may switch to other things instead. Several factors that influence warning legibility were presented. Other considerations relevant to attention maintenance, such as location, were also described. The main point is that the warning needs to be designed and have features and characteristics that aid in presenting the material while grasping and maintaining attention. People will not spend large amounts of time and effort studying a warning that they cannot read or have difficulty reading. The warning designer needs to consider where the warning will be placed, what materials to use, and how to deal with space constraints. More work by the warning designer up front will make less work for the reader and consequently more likely the information will be communicated.

Audition

Initially, an effective auditory warning alerts the receiver (Edworthy, Hellier, & Stanton, 1995; Hass & Edworthy, 2002; Stanton, 1994). After attention is switched, attention to the incoming auditory warning may need to be maintained over the time period it is being transmitted. Although this is less of an issue for short-duration auditory stimuli, with long-duration auditory stimuli, attention must be held while the message unfolds. This is likely true for voice communications, as speech requires more 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 the intelligibility of sound. Much of the work was done in military and aviation contexts. Several chapters in this Handbook detail the findings in this literature (Bliss & Fallon, chap. 17; Edworthy & Hellier, chap. 15; Haas & Edworthy, chap. 14, this volume). Some of the most important factors are described in the following.

Intelligibility can be affected by numerous message, channel, context, and receiver factors (Edworthy & Adams, 1996; Mulligan, McBride, & Goodman, 1984; Sanders & McCormick, 1993). Intelligibility is reduced by (a) low signal levels, (b) presence of high levels of masking noise, (c) low familiarity with the message by the receiver, (d) a wide ranging vocabulary within the message, (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. Intelligibility can also be compromised when a perfectly clear message is played back through defective or low-fidelity audio systems.

Annoyance and False Alarms. As noted earlier in this chapter, auditory warnings can alert, but they also may annoy and cause distraction from an important task. Highly intrusive sounds can interfere with the receiver's thought processes making some activities more effortful and error prone. People can also become quite disturbed when too many false alarms occur. High rates of false alarms occur because the sensitivity of the detection system is very high (Bliss & Fallon, chap. 17, this volume). Usually there is good reason for making the system highly sensitive, most notably when the hazard is severe. However, high false alarm rates can produce the cry-wolf phenomenon, in which people ignore the warning because they believe that it is not signaling a real event. Unfortunately, the warning might actually be appropriately signaling the hazard with possibly tragic consequences. Frequent false alarms can increase the likelihood that people will purposely attempt to defeat the system. For more information on this topic, see Bliss & Fallon, chap. 17 and Meyer, chap. 16; this volume).

Multiple Voice Warnings. Some systems employ multiple voice warnings. The problem is some of these systems do not account for the possibility that they might be deployed simultaneously, a situation that could be highly confusing to the operator. How does one deal with the possibility of several simultaneous speech warnings? Some possible solutions are:

- Presenting simultaneous messages in distinctly different voices that are discernable from one another (male vs. female vs. synthetic voice).
- Prioritizing the order of messages so that the most important are given first.
- Having messages appear to be coming from spatially distinct locations.
- Giving the most important message(s) prominence features (e.g., loudness) based on urgency.
- Enabling playback of the message if part of it is missed.
- Combining a concise voice warning with a more detailed print warning (Edworthy & Adams, 1996; Wogalter, Kalsher, & Racicot, 1993; Wogalter & Young, 1991).

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 (Conzola & Wogalter, 1999).

Implications. Intelligibility is important when voice is used to communicate hazard messages. Intelligibility depends on the background noise and hearing protection, among other factors. The voice should be distinctive and brief. In addition, the system should elicit few false alarms and not interfere with important safety-related current tasks that the individual may be performing.

OTHER ISSUES

In this section other issues associated with attention switch and maintenance processing are discussed.

Multimodal Warnings

As briefly noted earlier, auditory and visual warnings can sometimes be combined. A benefit of having both modalities involved in a warning system is that they provide redundant cues. If one modality is not available, then information will be available to the other modality. Visual and auditory cues can also be combined 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 are examples. Rumblestrips on roadways provide auditory and tactile alerting cues to reinforce the visual cues from the road such as a reduced speed limit sign, or imminent hazard.

Another example of multimodal cues is interactive warnings (e.g., Dingus, Wreggit, & Hathaway, 1993; Duffy, Kalsher, & Wogalter, 1995; Frantz & Rhoades, 1993; Hunn & Dingus, 1992; Wogalter, Barlow, & Murphy 1995). 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). The potential value of interactive warnings is that the tactile cues make it more likely that attention will be switched to printed warning material by breaking into the person's consciousness when attention is being tied up by other tasks (Frantz & Rhoades, 1993; Gill, Barbera, & Precht, 1987; Lehto, 1991; Rasmussen, 1987).

Overloading

Overloading occurs when the amount of information is more than a person is able or willing to process. Large quantities of warnings (many separate ones or a single extensive one) are less likely to attract and maintain attention than having a few brief warnings. The levels at which overloading occurs is not clear and probably depends on a number of factors. The concept is usually invoked in instances where a person may be exposed to many warnings for a brief period of time, and during that time, the person does not have the opportunity to review all that is present. However, it is not clear what limits there are, if any, over longer periods of time. Given the possiblity that hazards may need to be known immediately, then prioritizing hazard communications is critical (Vigilante & Wogalter, 1997). In such cases, the most important information should be placed on the product and less relevant, although important, material placed in an accompanying product manual or package insert (see also Wogalter, Barlow, & Murphy, 1995).

Overloading should not be confused with overwarning. Overwarning is the notion that there are too many warnings that people encounter in the world, and as a consequence of this inundation, it is thought that people will be less likely to attend to warnings. In other words, overloading means processing capacity is overwhelmed by the amount of information in a given situation, whereas overwarning concerns being adversely affected by one's overall life experience with warnings so that attention to warnings is decreased. Although overwarning is theoretically possible, research has not yet clearly verified that it occurs and what the parameters are. Nevertheless, it reiterates the point that careful planning is necessary in using and designing warnings, particularly in terms of prioritization of content, formatting, and placement.

Habituation

Habituation is an outgrowth of the attentional 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 memory, there is a reduced salience, and other stimuli of greater relative salience may attract and maintain attention away from the warning stimulus.

In a different and perhaps less obvious sense, habituation is an indication that there is some information in memory about the warning. However, this does not mean that all of the relevant information is known or remembered. Individuals might have incomplete knowledge yet not be motivated to seek all of the facts. The problem is when the individual habituates to a warning but has not yet acquired all of the information from the warning. Another problem is when a person habituates to the general appearance of a warning and does not give attention to another similar-looking warning. The latter issue will be discussed in more detail in the next section.

Several design factors may help to retard or counteract habituation. The first is to incorporate features that enhance conspicuity (size, color, loudness) that were described earlier in this chapter. Another method is stimulus change. This can be done by modifying the warning every so often so that it looks or sounds different. Technology has now enabled the ability to control warning presentation so that a warning is presented only when needed (see Wogalter & Mayhorn, chap. 63, this volume). One example is the increasingly more common electronic signs on roadways. In the workplace and in hazardous environments, warnings could be presented only during the points in time when the risk information is needed. Highly sophisticated detection and warning systems could also enable personalization of the sign (e.g., using the targeted individual's name) and varied presentation patterns (partial, irregular reinforcement) that will prevent or delay habituation (Racicot & Wogalter, 1995; Wogalter, Racicot, Kalsher, & Simpson, 1994).

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 types 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 every so often. For durable goods, such as appliances and power tools, it may sometimes be possible to send to consumers revised warnings for previously purchased products using databases containing registration, purchase, rebate/coupon, warranty, and repair records.

Standardization

As we have seen in the last two sections, frequently experienced events are less likely to attract and maintain attention. There has been an increasing effort in recent years to produce standards (see Deppa, chap. 37; Peckhom, chaps. 33, 35; Young, Shaver, Grieser, & Holl, chap 32; this volume) that specify certain design and content characteristics. An example is the ANSI (2002) 2535 format described earlier. A positive aspect of standardization is that, given its relatively consistent physical characteristics, people will eventually learn what a warning looks like. In this sense, a standardized warning placed in a cluttered environment will enable a person to pick out more easily the warning from the visual noise. A further advantage of standardization is that relatively little effort may be needed to produce a warning that conforms to the standard.

However, warning standardization has some important downsides that are not often considered. The foremost problem relates to the fact that standardization promotes similarity across all types of warnings that, in turn, is likely to exacerbate the previously mentioned problems associated with habituation. If all warnings look or sound about the same, then it is quite possible that over time they will lose their attention-getting value. Because attention is the starting point of information processing in the receiver, if standardized warnings lose their necessary attention-getting capacity, the warnings would not be serving their intended function and could result in disastrous consequences. Unfortunately, these problems have not been thoroughly considered by advocates for standards.

Standards and guidelines are good starting points for initial warning designs. But they are a minimum. Standards cannot specify what might be needed in a particular situation or for a particular product. Warning designers should deviate from the standards and guidelines when it is appropriate and necessary to do so, as the main point of warnings is safety, not consistency. Iterative design and testing can reveal other design variants that may be better. For example, test data show that the word DEADLY with a diagonal stripe border is more effective in capturing attention to a warning associated with a very severe hazard than the ANSI (2002) Z535 highest level word DANGER with its standard plain black border. With good data to support it, modifications from the standard's specifications that improve the effectiveness of warnings should not only be permitted, but also encouraged. Using only the specifications in warning design standards may fail to produce a warning that protects people's safety.

Processing Mode and Relevance

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

Stimuli that are personally relevant and interesting tend to attract attention. Because people's interests differ, people will look and listen to different things. A person's own name is one of the most relevant attention-getting stimuli. Moray (1959) found that auditory presentation of a person's name had a strong effect on attracting attention. Similarly, Wogalter, Racicot et al. (1994) showed that displaying a person's first name on an electronically presented warning sign led to higher compliance than a generic warning signal word (CAUTION) in its place. Thus, where possible, relevance should be considered in warning design.

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, whereas in other cases, the population is more constrained (e.g., military recruits, trained health professionals, etc.). Frequently, broad target audiences will contain individuals with some form of limited sensory capability, such as vision or hearing impairments in older adults (Mayhorn & Podany, chap. 26, this volume; Rousseau et al., 1998; Smith-Jackson, chap. 24, this volume; Wogalter & Young, 1998; Young, Laughery, Wogalter, & Lovvoll, 1999).

Some individuals have genetic color-vision deficiencies (color blindness). Many of these individuals cannot distinguish certain color differences, such as between red and green or between yellow and blue. These color combinations should be avoided as figure–ground combinations.

The warning designer should take care to consider the target audience's characteristics and where applicable, use designs likely to reach the relevant groups. For example, when designing for older adults, a basic design guideline is to make the warnings larger or louder (Laughery & Brelsford, 1991; Rousseau et al., 1998). Consideration may need to be given to the language ability and skill of users and may require text written in more than one language or the messages conveyed by symbols (e.g., Lim & Wogalter, 2003). It should also be recognized that although warnings may be targeted to specific groups, the hazard can be relevant to and affect others. For example, the driver of a tanker truck carrying a toxic chemical is a primary target for hazard communications regarding the chemicals, but should the truck overturn on a busy street, the hazard and the warnings become important for first responders and others.

Testing

How does one know whether a warning is adequate in its ability to switch and maintain attention? The best way to determine this capability is to test a representative sample of the target population. Other chapters in this volume (see Deppa, chaps. 37, 41; Fischhoff & Eggers, chap. 20; Wogalter, Conzola, & Vigilante, chap. 38) provide more information about testing methods. In this chapter, we briefly mention a few of the most pertinent testing considerations for attention capture and maintenance. Some of the basic methods include:

- Having individuals rate or rank the noticeability of various prototype designs.
- Having individuals take part in legibility or intelligibility assessments that might include the warnings being presented under degraded conditions such as at a distance or in background noise.
- Asking whether participants remember seeing or hearing a warning to which they were previously exposed.
- Measuring reaction time to detect the warning (where quicker response times indicate better noticeability).
- Recording looking behavior to determine whether and how quickly individuals orient to the warning (e.g., eye and/or head movement) and how long they examine or listen to it.

The best evaluations most closely replicate the real risk conditions and tasks. For example, measurement of looking behavior using a hidden camera is a more externally and ecologically valid assessment of warning salience than subjective ratings of noticeability in a questionnaire.

Inattentional Blindness

Inattentional blindness is a phenomenon where there is a failure to perceive a stimulus, even though it appears within our central vision. One suggested reason for this perception failure is that attention is selectively focused on another object or task and misses the seemingly apparent stimulus. Inattentional blindness is similar to change blindness, where observers fail to notice large changes to an object or scene from one view to the next, particularly if the changes occur in an area that is not the center of interest. Typically, inattentional blindness occurs because of the combination of the arrival of an unexpected stimulus and observer's selective attention to other stimuli. Attention does not have to be focused on an external stimulus to show the effect. It also may directed inward in the form of deep thought, day-dreaming, or other inward focusing of attention.

A dramatic example of inattentional blindness was demonstrated by Simons and Chabris (1999) who found that approximately half of their observers who were required to focus their attention on one of two simultaneous activities did not notice a gorilla nor a tall woman with an umbrella walk across the background of the scene. Inattentional blindness has also been shown to decrease the likelihood of target detection while driving when a complex conversational task is introduced that requires high demand on limited attentional resources (e.g., Recarte & Nunes, 2003).

Inattentional blindness may result in a warning possessing conspicuity-enhancing features (e.g., painted fluorescent orange) being missed by people engaged in a highly complex task or a task requiring highly focused attention. In these cases, the warning designer must determine how to best present the warning to increase the likelihood that it is detected and attended to. It may be necessary to increase the conspicuity of the warning by adding an audible alert, a flashing light, increasing the size of the warning, providing alternating colors, and so forth. It may also be necessary to devise a method to insert the warning directly into the task to enhance the detection likelihood (e.g., Conzola & Wogalter, 1999; Dingus et al., 1993; Frantz & Rhoades, 1993; Wogalter, Barlow, & Murphy, 1995).

Without taking into account the attentional demands of the observer, a warning may fail to attract attention because of inattentional blindness. Thus, a given warning may not be noticed in one attentionally demanding situation but is noticed in another less attentionally demanding situation. Warnings that have greater conspicuity are less likely to be affected by inattentional blindness.

CONCLUSIONS AND RECOMMENDATIONS

If people are unaware of an existing hazard, then they need to be warned about it. In the first stages of receiver processing, attention needs to be switched and then maintained on the warning. A more salient warning is more likely to attract attention and hold a person's attention than a less salient warning. Incorporating features that add prominence to the warning is generally desirable. The exceptions to this rule are those instances when the switching and maintenance of attention to a warning might add to the danger of the situation, such as a warning diverting a pilot's attention away from other important displays during critical times (e.g., high work load emergencies) or drawing a motorist's attention away from the road while driving in busy traffic. The problem here is when a highly salient warning is signaling a less critical event in comparison to other more critical concurrent events. Such possibilities should be considered in the design of warning systems.

In this chapter we focused on visual and auditory modalities involved in attention switch and maintenance. For visual warnings, factors discussed were contrast, color, size/visual angle, font, character spacing, case, legibility, formatting, highlighting, pictorial symbols, signal words, duration/flash rate, borders, separation or integration, location, limited space, printing, durability, environmental conditions, repeated exposure, and competing environmental stimuli. For auditory warnings, factors discussed were sensitivity, intelligibility, sound localization, interference, and multiple voice warnings as well as the problems of annoyance and false alarms. Other issues discussed included the use of multimodal warnings, overload, habituation, standardization, processing mode and relevance, target population characteristics, and test methodology. Because the design of warnings is a function of many factors, we offer a general set of recommendations or guidelines in the following.

To maximize attention to visual warnings, the warning 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 when possible.
- Present information by way of multiple features and modalities to serve as redundant cues.
- Have attractive formatting, for example, an outline or list format with spaces and bullets separating the main points instead of continuous, paragraph-type prose.
- Be durable for the life of the product or hazardous condition.
- Make use of the available surface area and use enlarged surface space or refer users to another accessible source for more information, if necessary.
- Be located when and where the information is needed.
- Be evaluated for effectiveness and modified when insufficient effectiveness is found.
- Be inspected and replaced, if needed.
- Have a varied appearance to reduce the effects of habituation.

To maximize the conspicuousness and maintenance of auditory warnings, the warning should:

- Be brief.
- Have a high signal-to-noise ratio, but not be so loud that it is overly annoying.
- Be clearly distinguishable from other warnings.
- Have low false alarm rates.
- Be adjustable for detection sensitivity.
- Be evaluated for effectiveness and modified if insufficient effectiveness is found.
- Be inspected and maintained and, if necessary, serviced or replaced.
- Have a varied sound to reduce the effects of habituation.

The warning development procedures should:

- Consider the sensory and mental 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.
- Test the warnings using methods that closely represent the desired behavior, if possible.

By incorporating these characteristics (and other recommendations suggested in this chapter), a warning is more likely to be successful in switching and maintaining attention. In doing so, it paves the way for additional processing.

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