The Aging Workforce

Implications for Warning Symbol Design

By Mary F. Lesch, William J. Horrey, W. Ryan Powell and Michael S. Wogalter

Employers have an ethical and legal obligation to inform all workers of the presence of hazards and methods of avoiding or protecting themselves from these hazards. Often, this communication takes the form of warning signs and labels. With increasing diversity in workplaces and worksites, symbols have become a critical component of warnings. Symbols have the potential to be understood by groups varying in language background and reading ability and, often, can be seen from greater distances than text.

However, several studies have shown that many warning symbols are poorly understood and that older adults have even greater difficulty understanding warning symbols (Hancock, Rogers & Fisk, 1999; Lesch, 2003; Hancock, Rogers, Schroeder, et al., 2004). Improving understanding of these age-related differences in warning symbol comprehension is critical since the workforce is rapidly aging—statistics suggest that by the year 2030, 25% of the U.S. population will be older than age 60 (Administration on Aging)—and

IN BRIEF
- To investigate age-related differences in warning symbol comprehension, younger and older adults were tested on their comprehension for symbols varying on familiarity, complexity and comprehensibility.
- Older adults' comprehension was poorer than younger adults both before and after training.
- More familiar and more comprehensible symbols were more easily understood by both younger and older adults, whereas high complexity symbols were more difficult for older adults. Following training, only comprehensibility showed a relationship with comprehension and only for older adults.
- To optimize comprehension by older adults, complexity should be minimized and symbols should have a clear relationship with a real-world referent. Alternatively, symbol design could incorporate cues to knowledge to facilitate the linkage between new knowledge and relevant knowledge in long-term memory.

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failures to communicate safety information can result in serious injury or death.

Age-Related Changes in Cognitive Processing

As people age, cognitive processes such as attention, language and memory decline. These age-related changes may contribute to the greater difficulty older adults have in understanding warning symbols. These changes are described as age-related since they tend to, but do not necessarily, occur with increasing age.

Older adults demonstrate a decreased ability "to effectively inhibit the processing of marginally relevant, irrelevant and/or distracting stimuli and thoughts" (Kane, Hasher, Stoltzfus, et al., 1994, p. 103) such that they may have greater difficulty focusing attention and shutting out irrelevant information. When attention must be divided across multiple tasks, older adults tend to experience greater dual-task costs. For example, older drivers experience larger decrements in driving performance than younger drivers while distracted (e.g., during cell phone use) (Hancock, Lesch & Simmons, 2003).

The ability to retain and recall information also changes with age. Older adults may be able to remember less information over the short-term and require more time than younger adults to retrieve or recall information (Baddeley, 1986; Kane, et al., 1994; Luo & Craik, 2008; Salthouse, 1985; Salthouse, Mitchell, Skovronek, et al., 1989). This is partly due to a reduced ability to tune out irrelevant information that competes with target information, resulting in longer retrieval time and/or the retrieval of incorrect information.

In support of age-related retrieval difficulties, research indicates that word-finding ability (Cohen, 1979; Pratt, Boyes, Robins, et al., 1989) and verbal fluency (McCrae, Arenberg & Costa, 1987) tend to decrease with age. For example, when retelling stories, the verbal output of older adults is characterized by fewer words (and details) and an increased frequency of pauses relative to younger adults.

Older adults also tend to show greater difficulty establishing and retrieving associative links between previously unrelated entities (Luo & Craik, 2008). One example is learning a second language. The sound and visual patterns that make up the words in the second language are, at first, unfamiliar to the learner. It is especially difficult for older adults to learn to associate unfamiliar words with meanings in their first language.

Implications for Warning Symbol Comprehension

Decreases in selective attention and the ability to turn off irrelevant information suggest that older adults would have difficulty with more complex symbols, especially if the additional information does not help them zero in on a symbol's meaning. The greater detail in more complex symbols may compete for limited attentional resources, making it difficult for older adults to focus on a symbol's most relevant aspects (see Figure 1).

Older adults' greater difficulty establishing and retrieving associative links between previously unrelated entities suggests that understanding and learning the meaning of abstract or arbitrary warning symbols also would be problematic. These symbols lack a clear relationship with a real-world referent.

More specifically, abstract symbols have a distant relationship with the concept, while arbitrary symbols have little meaning in and of themselves. On the other hand, representational symbols directly or closely relate to the concept. As Figure 2 shows, representational symbols resemble a snapshot or picture of a situation. A slightly different concept, comprehensibility, relates to how well a symbol can be understood without prior exposure or additional information—that is, how well it makes contact with long-term memory representations.

Representational symbols tend to be highly comprehensible since they directly represent (i.e., picture) their referent. However, a representational symbol might not be highly comprehensible if it does not sufficiently specify the concept it is intended to represent. For example, the symbol for safety shower (Figure 3) does not clearly specify that the shower serves a special safety function (i.e., aid in decontamination from dangerous chemicals).

Do Older Adults Have Greater Difficulty With Certain Types of Symbols?

To answer this question, Lesch, Horrey, Wogalter, et al. (2011), examine both younger and older workers' comprehension of symbols that varied in terms of familiarity: "Before today, how often did you encounter this symbol?" This was rated on a scale from 1 to 5 (not at all to very frequently); complexity ("how complex is this symbol—not at all complex to extremely complex"); and comprehensibility ("Pretend you are seeing this symbol for the first time and that you know nothing about it. How likely do you think it is that you could guess that it means [symbol label]?") Figure 4 (p. 48) provides an example of symbols, varying in terms of comprehensibility. Another key question is whether training improves comprehension of symbols by younger and older workers.

Experimental Setup

Fifty "younger" adults between age 18 and 35, and 51 "older" adults between age 55 and 77 participated in the study. The research team purposely uses the terms *younger* and *older* to reflect a relative difference in age rather than an absolute classification as young or old. While the older age group might be more appropriately described as middle-aged (Nichols, Rogers & Fisk, 2003), the team se-
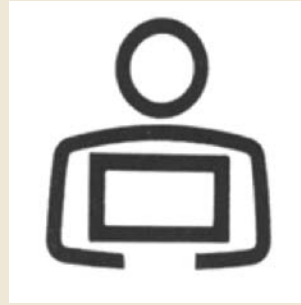
Figure 2
Symbols of Varying Representativeness
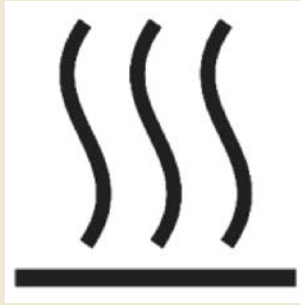
| No entry | Hot surface | Handle with care | Slip hazard |

Arbitrary --Abstract ---Representational

lected these age ranges to 1) represent working age adults and 2) maximize the likelihood of observing age-related differences in warning symbol comprehension.

Forty-six symbols varying in terms of familiarity, complexity and comprehensibility were selected for use in the study. These symbols represented various industries including (but not limited to) medical, chemical, construction, laboratory and manual materials handling. On a scale from 1 to 5 (not at all to extremely), familiarity ranged from 1 to 4.7 (M = 2.3, SD = 1.0; complexity ranged from 1.2 to 4.6 (M = 2.9, SD = 0.9); and comprehensibility ranged from 1.4 to 4.6 (M = 2.8, SD = 1.1).

Participants' comprehension of these symbols was measured, both before and after receiving training, using a semantic relatedness task (Lesch, 2003) in which the participant views each symbol twice: once with a label that conveys the symbol's meaning (i.e., the correct label) and another time with a label that does not convey its meaning (i.e., the distractor label). The participant's task was to determine, as quickly as possible, whether the label (correct or distractor) conveyed the symbol's meaning. Participants then reported their level of confidence in their decision from 1 (not at all confident) to 5 (certain). Distractor labels consisted of incorrect (but plausible) responses given by participants as open-ended responses (i.e., in response to the question "What does this symbol mean?") in earlier studies (Figure 5, p. 49).

In the training phase of the study, each symbol was paired with an accident scenario that described an accident or close call related to the hazard indicated by the symbol. The accident scenarios further elaborated on the hazard's nature and recommended actions, as well as the possible consequence of failing to perform these actions (Figure 6, p. 49). Earlier research (e.g., Lesch, 2008a) found that the accident scenario training provides additional benefit beyond provision of the symbol's meaning (i.e., label) alone. The goal of the current study was to examine whether older adults' comprehension would vary as a function of symbol characteristics and to determine the effectiveness of accident scenario training in addressing comprehension difficulties associated with symbol characteristics.

Results & Discussion

A symbol was considered to be understood if the participant both accepted the correct label ("yes, the label corresponds to the meaning of the symbol") and rejected the distractor label ("no, the label does not correspond to the meaning of the symbol"). Confidence ratings were combined with accuracy scores to produce composite confidence scores (ranging from 1 to 10), which were highest when the correct answer was accepted with certainty *and* the distractor was rejected with certainty. The confidence ratings should reflect the strength of the associated knowledge; that is, a certain *yes* reflects a stronger memory representation/activation than a somewhat confident *yes*.

First, the researchers determined that training was effective in improving comprehension as well as speed of responding to the symbols. Overall, average composite confidence scores improved from 5.9 before training to 8.3 following training. Rate of improvement was similar for younger and older adults. Overall, however, composite confidence scores were significantly lower for older adults (7.1) than for younger adults (7.5). Training also allowed participants to respond 2.2 seconds more quickly to the symbols following training. However, on average, younger participants responded 1.5 seconds faster than older participants.

Next, the research team determined whether the differences observed in comprehension by younger and older adults could be understood in terms of the familiarity, complexity or comprehensibility of the symbols. Before training, the group found that both more familiar and more comprehensible symbols were more easily understood by both younger and older adults. However, for older adults, if a symbol was too complex, its comprehensibility made little difference. High complexity appeared to limit older adults' processing of the symbol such that com-

Arbitrary symbols have little meaning in and of themselves. Abstract symbols have a distant relationship with the concept. Representational symbols directly or closely relate to the concept.

Example of a symbol that might not be adequately comprehensible. Specifically, this symbol does not distinguish between a regular shower facility and the safety function served by a safety shower.
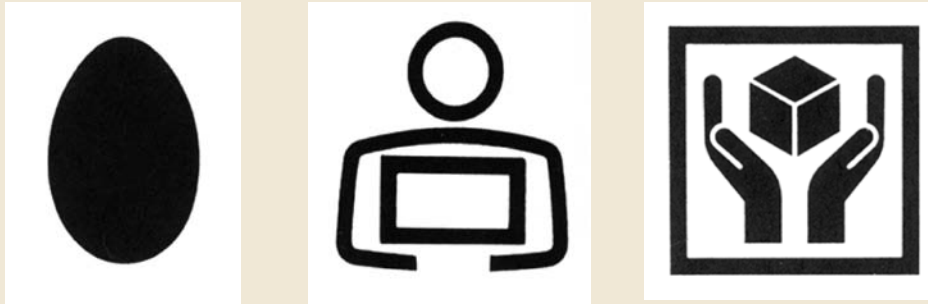
Figure 3
Inadequate Symbol

Safety shower

Figure 4
Varying Comprehensibility

Three different symbols for *handle with care* that vary in terms of comprehensibility (left to right, lower to higher comprehensibility).

Handle with care

prehensibility did not have an opportunity to influence comprehension.

Following training, none of the symbol characteristics appeared to influence comprehension by younger adults, suggesting that training had successfully addressed comprehension difficulties associated with these characteristics. However, for older adults, comprehensibility continued to influence symbol comprehension. This finding suggests that older adults' learning of warning symbols also is dependent on the comprehensibility of the symbols.

Conclusions

It was hypothesized that due to age-related changes in attention, language and memory, older adults would have greater difficulty with more complex and less comprehensible symbols. As in earlier studies, the researchers found that older adults have greater difficulty than younger adults in comprehending warning symbols and that accident scenario training improves comprehension and confidence in responses, as well as speed of responding.

The team also found that both familiarity and comprehensibility of the symbols exerted a significant influence on pretraining comprehension for both younger and older adults and that symbol complexity moderated the effect of comprehensibility for older adults. After training, comprehensibility continued to influence comprehension for older adults. This result suggests that comprehen-

sibility plays an important role in learning by older adults; despite training, comprehensibility continued to predict comprehension performance.

Accident scenario training can be thought of as increasing familiarity with the symbol and providing additional contextual information for the symbol (e.g., situations in which the symbol is likely to be seen, nature of the hazard, how to respond to it, possible consequences of failing to respond). However, increased familiarity was not enough to improve older adults' comprehension of less comprehensible symbols.

Therefore, an important question is whether the design of less comprehensible symbols can be improved to facilitate learning. For the most part, older adults' comprehension of less comprehensible symbols did not benefit from training. However, there were notable exceptions. One example is the symbol for cancer-causing substance (Figure 5). This symbol includes a broken circle that is intended to indicate cell mutation, as well as a verbal retrieval cue—namely, the letter *C* for cancer.

Initially, older adults' comprehension of this symbol was poor since it is a relatively abstract, less comprehensible symbol. However, comprehension improved with training since older adults learn that "C is for cancer," which reinforces memory. The researchers suggest that these cues facilitate the linkage between new knowledge (i.e., the warning symbol) and relevant knowledge in long-term memory. In essence, the cue helps to make the new knowledge "old," or already known, by providing a clearly recognizable and familiar piece of information that relates the new information to already known information.

One limitation of this study is that the research team was unable to vary the symbol characteristics independently in order to more definitively determine their relative contributions. Therefore, some caution must be taken in interpreting the results. However, the team can make some recommendations regarding symbol design:

1) Symbols should be visually simple and representational. Simple and direct is best.

2) With regard to complexity, increased detail should be relevant and necessary in communicating the symbol's meaning.

3) If a symbol must be abstract, it should not be arbitrary (since arbitrary symbols have little meaning in and of themselves).

Symbol Policies

Companies and organizations should establish specific policies on the use of symbols to communicate hazardous situations to older workers. These policies include:

- •Symbols should be visually simple and representational. Simple and direct is best.
- •With regard to complexity, increased detail should be relevant and necessary in communicating the symbol's meaning.
- •If a symbol must be abstract, it should not be arbitrary.
- •If abstract or arbitrary symbols must be used, including contextual or verbal cues in the design may facilitate initial symbol comprehension as well as increase training effectiveness.
- •Provide training to help address comprehension difficulties experienced by younger and older workers.

4) However, if use of abstract or arbitrary symbols cannot be avoided, including contextual or verbal cues in the design may facilitate initial symbol comprehension as well as increase training effectiveness.

5) Learnability can aid in the selection of the best symbol from a set of symbols of similar comprehensibility.

Research indicates that there is substantial benefit to providing accident scenario training—training significantly increases accuracy, confidence in responses and speed of responding (Lesch, 2008a, 2008b). By strengthening the association between the symbol and its required/prohibited actions, the accident scenarios should increase the symbol's ability to automatically trigger appropriate responses.

It also has been found that accident scenario training can shift attitudes toward safety (Lesch, 2008b). When symbols cannot be redesigned, accident scenario training provides a simple, cost-effective means of improving comprehension. While these design and training recommendations are especially important in ensuring older adults' comprehension and memory for warning symbols, this study's results indicate that they should benefit younger adults' comprehension as well. **PS**

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