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Identifiability and effectiveness of graphic symbols used in warning messages

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Rice University, 1990

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IDENTIFIABILITY AND EFFECTIVENESS OF GRAPHIC SYMBOLS USED IN WARNING MESSAGES

by

DAVID L. MAYER

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IN PARTIAL FULFILLMENT OF THE
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IDENTIFIABILITY AND EFFECTIVENESS OF GRAPHIC SYMBOLS USED IN WARNING MESSAGES

by

David L. Mayer

Abstract

Warning signs and labels are on many consumer products and in many public places, and in this increasingly technical world, these warning messages often provide critical information necessary to one's safety. But, many Americans cannot read English. Graphic symbols have been suggested as a means of communication with these users as well as those who can read. Three experiments regarding the effectiveness of pictograms in warnings were conducted. Experiment 1 investigated pictogram identifiability. Identification rates ranged from 2 to 95%. Experiment 2 studied pictogram communication of injury avoidance information. Pictograms did not uniformly cue this information. Experiment 3 investigated how pictograms affect hazard perception. The presence of a pictogram in a warning message was found to increase perceptions of hazard, especially where an external, easily-represented hazard referent was concerned. It is concluded that pictogram comprehension is a function of identifiability as well as injury communication and hazard perception.

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Review of the Literature

Introduction

Recent years have seen a proliferation of warning systems. Warning signs and labels are on many consumer products and in many public places. In an increasingly technical world, these warning messages often provide critical information necessary to one's safety . But despite living in this technical world, many Americans cannot read English. Exact numbers are impossible to determine (Smith et al., 1986), but, it has been estimated that between 17 and 21 million adults in the U.S. are illiterate, and a 1975 University of Texas study concluded that one in five Americans cannot read well enough to perform such tasks as writing a check or addressing an envelope (Bowen, 1986). The Department of Education estimates that due to immigration and high school attrition the number of illiterates grows by two million every year (Bowen, 1986). Obviously, to a large segment of the population, critical, English-language safety information is meaningless. The use of symbols to assist in conveying warning messages either for consumer products or in the industrial setting has seemed a potential solution to this problem.

Written language began through the use of pictures to represent ideas. The current alphabet has evolved well beyond a collection of concept-expressive picture-symbols and now requires training and practice to be useful (Giedion, 1966). Consequently, if one has not received instruction in a particular language, or is for whatever reason unable to understand it, textual messages displayed in that language will be of no utility. Easterby (1970) finds it paradoxical that in this time of great technological advancement, we are

forced to retreat to the language style of the ancients to communicate complex ideas. But if this pictorial method of communication is not what out modern world calls for, perhaps it can at least augment our present-day written communication.

Potential advantages. A number of potential advantages of graphic symbol communication have been noted. It has been suggested that symbolic communication has the advantages of simplicity, unambiguity and understandability even where the recipient of the message does not know the written language (Mead & Modley, 1968). In addition to overcoming language barriers, Modley (1966) has suggested that symbols stimulate visual thinking. Thus, a driver approaching a curve in the road who sees a symbolic representation of the upcoming curve does not first have to convert a textual message into a spatial representation of the road ahead. It follows then that a worker who observes a pictorial representation of a pinch point between rotating gears may have a clearer picture of the danger than one who is presented with a textual representation of the same hazard. These authors suggest that these advantages of symbols "create a direct and immediate impact and this permits immediate response" which "saves thinking" (Mead & Modley, 1968, p. 57).

Another feature of symbolic communication is its spatial compactness. A portion of an object (such as a telephone handset) can be used to convey a complex message such as the location of a public telephone (Kolers, 1969). As Kolers points out, this is at once an advantage as well as a limitation of symbolic communication, because compactness is achieved"through greater reliance on the reader's memory and interpretative powers" (Kolers, 1969, p. 355). He further claims that the immediacy and directness of symbolic

communication are mediated by the cognitive demand of symbolic communication on the interpreter and thus are exaggerated. It is Kolers (1969) position that symbols can never completely replace written text, but can be useful for identifying and locating objects and for providing instructions.

Limitations. While there are potentially promising advantages for the use of symbols in warning systems, there are a number of potential limitations which must be considered when choosing exactly what will be presented graphically. There has been much concern about the lack of a grammar of symbology (Kolers, 1969; Drake, Mablin & Shaw, 1979). Despite this lack of combinatorial rules, symbols are often combined, especially to represent the prohibition of some action. These are generally constructed by superimposing a slash over a symbol which depicts the prohibited activity. However, because the slash often obscures the symbol, it has been suggested that symbol designers use positive rather than negative symbols whenever possible (Modley, 1966; Dewar, 1976). Of course, this is not always possible. Some messages, such as *no smoking* require the use of a prohibition message because a symbolic representation of appropriate behavior would be ambiguous.

There are a number of types of messages for which symbols are marginally or not at all useful. Symbols cannot comment on or evaluate information (Kolers, 1966), they are poor at representing processes or activities or changing situations (American Institute of Graphic Arts, 1974, 1979). Limitations are also introduced when two-dimensional symbols are used to convey three-dimensional information (Modley, 1966). Modley noted that because highway signs cannot depict an arrow pointing straight ahead, an arrow pointing up has come to mean *proceed forward*. Yet this same symbol

associated with an elevator would mean *up*. Audiences must be able to adjust to these commonly used symbol elements in new situations without becoming confused.

Despite the enthusiasm of Mead and others, symbols can rarely communicate all of the needed information by themselves (Eliot, 1960a). Experience and textual features as well as shape and color often must be relied upon to convey the entire message. Context can also be a critical factor in symbol comprehension. Modley (1966) suggested that a pictorial depiction of a cow might not reasonably be expected to communicate the idea of a cattle crossing unless seen in appropriate context. And Dreyfuss (1966) recommends that symbols for machine operation be located near the controls and displays to which they relate. Finally, there is the question of the limitations of the audience. Because experience plays a critical role in the interpretation of symbols, a symbol for an elevator cannot be reasonably expected to mean anything to an audience which has no experience with elevators. Some symbols, such as those for radiation or lasers, require some formal indoctrination before they can be meaningful. This limitation may not be overly critical in a restricted, technical target audience, but is an important consideration where symbols are designed for general use.

Evaluating symbols. Because of the large number of potential limitations of symbol communication effectiveness, thorough evaluation of any symbol design is critical. Collins (1982) describes two basic strategies for symbol evaluation: design evaluation and effectiveness evaluation. She suggests that input received during the symbol design phase can contribute to the development of a meaningful symbol. But, she cautions that this essential stage does not replace the need for assessment with the intended

target population. "Ideally, symbol effectiveness should be evaluated from the twin viewpoints of graphic integrity and conceptual meaningfulness" (Collins, 1982, p. 17). Sloan and Eshelman (1981) have suggested that it is desirable to solicit feedback from members of the target audience even during the design process, though this is rarely done.

It has been suggested that a review of the symbol design can help avoid common failures of symbols (Dreyfuss, 1966; Easterby, 1967; Collins, 1982). Modley (1976) listed conceptual failure, poor draftsmanship, poor use of color, inconsistent use and conflicting meanings as common failures of symbols. Many of these flaws can be identified and eliminated by non-empirical reviews which occur early in the design process. Further, Easterby (1970) has written of the importance of perceptual principles such as Gestalt psychology to the design of symbols. He called for stable figure-ground relationships, simplicity and symmetry of design elements, and a general adherence to other Gestalt principles. He asserted that a good symbol is both *discriminable* from other figures and *meaningful* on its own. Eliot (1960a) has held that a good symbol contains a bold outline and a minimum of fine detail and that asymmetry and discontinuity should only be used where they add meaningfulness.

After every attempt to produce a set of symbols of the highest graphical quality has been made, the set should be subjected to empirical target audience evaluation. Easterby (1970) advocated speed and accuracy of recall after training as an appropriate target audience evaluation technique as opposed to requiring subjects to supply a meaning for a symbol upon initial presentation. Citing the questionable efficacy as well as the existence of such training programs, Collins (1982) has argued for the utility of initial

presentation tests of meaningfulness, especially with regard to building safety symbols. Collins and Pierman (1979) evaluated a set of fire safety symbols. A test requiring subjects to supply a meaning for these symbols was appropriate because occupants of buildings employing the symbols being evaluated would not have any training with regard to their meaning. They found confusability with regard to the symbols *for exit* and *no exit*—a potentially fatal lack of discriminability which would most probably have remained undetected without this type of evaluation procedure.

With regard to the evaluation of symbol effectiveness, Collins (1982) has suggested a set of six questions which must be answered to evaluate a given symbol set thoroughly:

1. Can the symbol be detected?
2. Can it be discriminated from all other symbols?
3. Can it be recognized when seen in a different context?
4. Does it consistently communicate the intended meaning?
5. Does it get the user's attention?
6. Does it alter behavior appropriately?

The first question is a matter involving such issues as size, contrast and lighting which can only be fully answered in context. The second question follows Easterby's (1970) idea of discriminability and is calculated to avoid symbol confusions. Question three is related to the notion that once the meaning of a symbol is understood, the knowledge should be stable across different contexts. According to Collins (1982), question four is only true if the symbol communicates the same message to all users who see it. This, unfortunately, seems overly optimistic, and it is anticipated that a lower limit of acceptable identification will have to be established for most symbols. Standards for symbol acceptability (International Organization for Standardization, 1979; American National Standards Institute, 1987) recognize

that acceptable symbols will not always communicate uniformly to all users. Number five recognizes that part of a symbol's purpose, apart from message communication, is to attract the interest and attention of members of the target audience. The final question is, of course, the key question with regard to safety. If the symbol has no effect on behavior, it is of little use.

Though few validation studies explore all of the above areas, review will be made of several studies from different areas of symbol use: highway signage, automotive and machinery applications, public information and building safety, and finally safety warnings. Though the focus of the present research is primarily safety warnings, information gained from studies in all these domains can be useful to the understanding of safety symbol communication, thus the most relevant studies which have implications for safety warnings from each of these domains will be discussed.

Highway Symbols

The first standardized symbols for European highway signage were adopted by an international panel in Paris in 1909 (Eliot, 1960b). Symbols were adopted for rough road, curve, railroad crossing and cross roads. More symbols were adopted and the triangle was approved as the shape of warning signs at another conference in 1916. In 1931 the League of nations laid down uniform guidelines for color and sign shape and the number of approved symbols was increased to 26. In the United States, a convention of the American Association of State Highway Officials met in 1925 and adopted a standardized set of textual signs. It was not until 1971 that U.S. highway signs began to use symbols (Collins, 1982). Much of the early work on highway signs involved comparing symbols (the European method) with their textual equivalents (the then-current U.S. method).

One of the first such comparison experiments was reported by Janda and Volk (1934). They compared 20 highway directional signs by asking 160 subjects to move a lever in the direction indicated by the message on the sign. A facilitation of about 200 msec was found for symbols over words. They concluded that symbols were a more effective communication means than words alone, but suggested that a combination of words and symbols might provide the most easily learnable signs. Walker, Nicolay and Stearns (1965) also compared European style highway signs to the word signs which were then currently in use. After a familiarization phase, 70 undergraduate subjects were tachistoscopically presented with signs of both types and asked to identify them. The international symbols were identified more accurately by both genders. A subset of the subjects participated in a retention test 24 hours later in which they were asked to supply a meaning for the international symbols. All of these subjects demonstrated perfect recall. The authors concluded that because of their ease of interpretation, the use of symbols should could lead to safer highways as well as safer industrial settings.

Ells and Dewar (1979) again evaluated symbol versus word signs using a slightly more sophisticated paradigm. They read a message out loud to subjects and followed it by a visual presentation of a traffic word or symbol sign. The subjects' task was to respond yes or no depending on whether the verbal and visual messages were the same. A second study introduced degraded viewing conditions into the visual portion of the task. Greater response latencies were found for the word signs and the degraded conditions were found to increase latencies for both words and symbols. Symbols, however, were generally responded to faster than words under the degraded

as well as the normal viewing conditions. The authors concluded that symbols were generally superior to words and that this superiority generalized over a broad range of degraded environmental conditions such as fog, darkness and rain.

Studies of traffic symbols have also focused on identifiability of the symbols. Brainard, Campbell and Elkin (1961) used several techniques to assess the meaningfulness of 30 European traffic symbols. Some subjects participated in a definition matching test while other subjects were asked to supply a definition of their own for each symbol. Another group of subjects was asked to sketch a symbol for a given definition. The authors found that, generally, those symbols which were well identified in the first two phases were also the symbols which tended to elicit common sketches in the drawing phase. They also found that the addition of a prohibitory slash, which was uncommon in the U.S. at the time of the study, often reduced the identifiability of a given symbol. They concluded that the best symbols were those which were direct pictorial representations or those which relied on common stereotypes revealed during the sketching phase.

Additional research on highway symbols has examined behavioral compliance under actual driving conditions. Forbes, Gervais and Allen (1963) used a laboratory study to select the best of five symbols to indicate a closed highway lane. This symbol—a red *X* mounted above the traffic flow—was confirmed by field research to be the most effective. Dewar and Swanson (1972) compared the effectiveness of positive- and negative-message *no left turn* symbol signs by counting illegal left turns. They found the positive-message sign was more effective than the prohibitory sign. Unfortunately, neither of these behavioral studies directly compared symbols to word signs.

Research on highway signs has generally indicated that symbolic communication is superior to textual messages alone, especially under the degraded conditions that often accompany highway driving such as rapid presentation and poor lighting. This demonstrated superiority and general acceptance of Highway symbols has led to the use and study of symbols in other applications.

Machinery and Automotive Applications

While several automotive applications of symbols have been tested only a few machinery applications have been studied. Cahill (1975) tested a set of 10 symbols for farm equipment designed, but not tested, by Dreyfuss (1966). The symbols had such referents as horn, choke and handbrake. Using mechanical engineering students with varying degrees of experience with farm equipment as subjects, Cahill assessed symbol identifiability both in and out of context. She found a wide range of identifiability which was best in context and by subjects with greater experience, though the same ordering of identifiability was found when symbols were tested without context. Cahill concluded that context and experience are important factors in symbol identifiability. Sex effects could not be examined as no females were included in the sample. Because Dreyfuss had developed the symbol set without testing it on a target audience sample, and because some symbols were found to fare quite poorly, she further noted that evaluation of a symbol set on a sample of potential users is a necessary and often neglected step.

While studies have shown symbols to be generally preferred to textual displays, McCormack (1974) reported that males were more likely to be able to recognize and also quicker to identify symbols than were females. Frank, Koenig and Lendholt (1973) also found females to be less successful at

pictogram identification, but Jack, Heard and Pew (1970) found no such gender effect. With regard to age effects, Frank et al. (1973) found that subjects under age 30 were better able to identify symbols than were older subjects, while McCormack (1974) found no such facilitation. Clearly age and gender are factors which deserve more study with regard to their effect on symbol identifiability and perception. Noting these conflicts in the literature, Green and Pew (1978) studied 19 symbols developed for use in identifying automotive controls and displays.

In their study, Green and Pew (1978) used several procedures to evaluate the set of automotive pictograms. First, to determine prior experience, subjects were asked to indicate which symbols they were "reasonably sure" they had seen on the instrument panel of a car before (p. 105). Secondly, association norms were determined by reading 19 driving scenarios which referred to a particular instrument panel control. Subjects were asked to point to the pictogram associated with the referent control at the end of each scenario. Next, a rating task was used to allow subjects to make ratings of each symbols *communicativeness* which was defined as "how well a symbol suggested its designated name" (p. 107). Finally, the authors employed a paired-associate learning task. Subjects were sequentially presented with each pictogram and asked to say its meaning out loud, the correct name was then given immediately by the experimenter. This was repeated until each subject correctly named each pictogram. The test phase was similar to the same-different paradigm used by Ells and Dewar (1979). The experimenter read the name of a symbol aloud, then presented the subject with a slide of a pictogram. The subject pressed one of two buttons to

indicate if the pictogram presented correspond to the verbal referent or not. The latency to make this same-different decision was measured.

Green and Pew's (1978) results showed subjects to be generally unfamiliar with the pictograms—the mean number of symbols recognized was 2.6 of a possible 19. For the paired associate learning task, only 6 of the 19 symbols met the acceptability criteria of 75% identifiability and several common confusions were revealed. The rating task produced a wide range of subjective communicativeness ratings suggesting that some pictograms conveyed their message much better than others. The learning task demonstrated that despite initial errors, subjects were generally able to become quite proficient with the symbols. The authors concluded that gender was related to initial-presentation identifiability only. Contrary to Cahill (1975) they also concluded from correlational analyses that familiarity was not related to ability to learn or identify the symbols. Some range restriction may have been present, however, as all subjects in the Green and Pew (1978) study were licensed drivers. Not all of Cahill's (1975) subjects had direct experience with farm equipment. Because the communicativeness ratings were highly correlated with the association norms and paired-associate reaction times, the authors concluded that these subjective ratings could be used to estimate the empirical measures. This seems a dangerous assumption inasmuch as it could be interpreted to mean target audience symbol evaluation could be accomplished with no performance data. Zwaga (1989) has suggested a similar paradigm designed to make more efficient use of time without eliminating target audience comprehension testing of public information signs. His work is described in the next section.

In summary, research on automotive applications of graphic symbols has shown a general tendency for symbols to preform in a fashion superior to textual messages. But this research has also clearly demonstrated that without empirical evaluation of symbol sets, one cannot assume that each symbol has equivalent meaning to all members of the target audience. More recent symbols research has concerned both safety and informational signage applications in public buildings.

Public Buildings

Several sets of graphic symbols for public buildings have been designed and a number of researchers have conducted target audience evaluations of them. Fire safety symbols (Lerner & Collins, 1980b; Pierman & Lerner, 1980) as well as exit directional indicators (Lerner, 1981) have been tested. Mackett-Stout and Dewar (1981) compared four previously developed symbols for each of eight public information messages in a study designed to determine which symbol was best for each referent. Referents included such concepts as elevator, men's washroom and hotel information. The authors point out that conflicting results of previous research as well as varied testing methods suggest the need for evaluation of symbols using a variety of techniques. They conducted measures of glance legibility, legibility distance, comprehension and symbol preference. Of most relevance here is the comprehension study. Subjects were divided into four groups and one version of each symbol was shown to each group. Subjects were asked to write down what they believed to be the meaning for each pictogram. Significant differences were found among the competing symbols for five of the eight referents. Many common confusions were revealed. For example, the symbols for car rental which all depicted some version of an automobile

and keys were often thought to be parking symbols. The authors note the importance of using procedures of this type to identify weak or confusible symbols before they are used in public places.

Other studies of public information signs have led to similar findings. Zwaga and Boersema (1983) studied railway station symbology for Netherlands Railways using a matching paradigm. In general, the authors found that younger subjects and subjects with more experience using the railway were better able to match the symbols to their referents. Applying a criterion of 67% identifiability, only about half of the 29 symbols tested were considered acceptable for use. Several confusions, some language-related, were found. For example, a symbol for parking containing the letter "P" was often thought to refer to ticket information, apparently because the Dutch word for ticket is *plaatskaarten*. Zwaga (1989) has also evaluated a set of 109 hospital symbols from four symbol sets using subjects' estimates of comprehensibility in an attempt to shorten the testing procedure recommended by the International Organization for Standardization (ISO). The ISO procedure calls for a subjective ranking test to identify the most promising symbols from a larger set. Usually the three highest ranked symbols for a given referent are then subjected to a comprehension test where new subjects are asked to supply a meaning for them. Boersema and Zwaga (1989) used this procedure to evaluate a set of swimming pool safety symbols. Zwaga (1989) presented subjects with hospital symbols and their referents and asked them to estimate the percentage of the population which would be able to interpret each symbol. Using another set of subjects, a comprehension test was given in which subjects were asked to supply meanings for each symbol. The comprehension estimates given by the first set of subjects were found to

explain between 63 and 93% of the variance of the comprehension test scores depending on the symbol set tested. He concluded that the ISO testing procedure can be shortened by using the former as an estimate of the latter. He recommends, however, the inclusion of an uncertainty range about the 67% criterion. Using this uncertainty range, very good and very bad symbols can be eliminated from the comprehension test, thus greatly reducing the number of symbols to be tested in this manner. The research program of Zwaga and his colleagues has led to some of the most thorough evaluations of public information symbols and has encouraged a great deal of work with warning symbols.

Warning Symbols

Collins, Lerner and Pierman (1982) conducted one of the first and most extensive evaluations of the use of warning symbols. They gathered between two and forty symbols for each of 33 referents. The referents selected were common general industrial hazards such as flammable material, rotating gears, electrical and radiation hazards. Graphics experts rank ordered the symbols for appropriateness for each of the referents and these rankings were used to choose three to five symbols for each referent for further testing. A sample of 222 subjects employed in industrial settings (*informed* subjects) and a sample of 78 non-industrial subjects (*naive* subjects) were assembled for testing the symbols. In the first phase, subjects were shown one symbol for each referent and asked to provide short definitions for each symbol. In the last phase, subjects were shown all competing symbols for each referent along with the intended meaning and asked to indicate the symbol which best conveyed the message to them. The authors found that the percent correct and the number of symbol confusions varied widely among the referents as

well as among the symbols tested for each referent. The pattern of results exhibited by the industrial subjects was similar to that of the naive subjects, but no statistical comparisons were made. Symbols for laser, biohazard and radiation were often misidentified, while symbols for protective, emergency and first aid equipment were generally well understood. They found wide variability in meaningfulness among the symbols tested for the rotating gears, electrical, chemical and overhead hazards. No sex or age differences were reported. Finally, a high correspondence was found between symbol preference and understandability.

Otsubo (1988) conducted a behavioral study to evaluate the effectiveness of pictograms in warning labels. A pilot study showed subjects perceived a circular saw to be more dangerous (greater likelihood of injury and greater injury severity) than a jigsaw. She used a 2x4, between subjects design incorporating these two levels of perceived product danger and four levels of warning design: words only, pictogram only, pictogram plus words and no warning. The warning message, in whatever form conveyed a message regarding the sharp blades of the saw and the need to wear gloves for protection. Subjects were taken to a realistic workbench and told that they would be using an electric saw to repair a bookcase. Hand tools and protective equipment including gloves were available along with the saw. Where a warning label was to be present, it was affixed to the handle of the saw. Subjects were given some specific instructions regarding a piece of lumber they were expected to cut, and then subjects were observed preparing to use the saw. The procedure was terminated when subjects pressed the power switch to use the saw, which was not connected to a live power source.

Whether gloves were donned before attempting to use the saw as well as several responses to a posttrial interview and questionnaire were recorded.

As expected, more subjects noticed, read and complied with the warning on the circular saw than for warning on the jigsaw, but the compliance data were not impressive. Only 38% of the subjects planning to use the circular saw actually put on gloves and only 13% of the potential jigsaw users wore gloves. With regard to compliance with the circular saw warning, the words plus pictogram warning was only marginally more effective than the words alone warning and the pictogram-only warning was least effective. The poor performance of the pictogram alone, along with the relatively small increase in compliance found when it was added to the textual warning, may be more an indictment of the pictogram used than a test pictogram effectiveness. The graphic is complex, involves a combination of graphic elements to show the process of gloving a hand and makes use of inconsistently sized elements. The use of a better figure or the testing of a number of symbols might have revealed more pictogram facilitation.

Friedmann (1988) used a behavioral paradigm to test pictograms which either depicted an appropriate hazard avoidance behavior such as using protective equipment or which showed the consequences of not using this protection. She termed these *proactive* and *reactive* pictograms. The study was a 3x2x2, between subjects design. Three levels of warning type were used: text only, text plus a proactive pictogram and text plus a reactive pictogram. Two levels of product familiarity (high and low) were used by employing a common product, liquid drain opener, and a less common product, liquid wood cleaner. Nonhazardous substances were substituted for the products. Two levels of compliance behavior were used: subjects were either required

to wear a respirator to protect against fumes or to wear goggles to protect against eye contact. Subjects were presented with either product in an appropriate situation for its use. They were told to read the back panel of the product labelling and use the product. The subject was observed for compliance behavior and the procedure was terminated when the subject opened the product container. Overall, only 27% of the subjects complied with the warnings. The addition of a symbol to the written warnings did not significantly increase the likelihood of reading the textual message. Though subjects perceived the products with the pictogram warnings to be more hazardous, this did not translate into any significant effects of compliance. There was no effect of symbol type on compliance. In a recall test, Friedmann found that the proactive symbol for the inhalation hazard was recalled significantly more often than the other three symbols. She postulated that the better graphic qualities of this symbol might be responsible for this finding. It is also possible that aspects of symbol design did not provide a best-case test for the symbols used. The reactive symbols did not clearly depict any injury except a watery eye for the eye injury symbol. Had symbols which more clearly depicted the consequences of non-compliance been used, an effect for hazardousness and severity related to the pictograms might have been observed.

What It All Means

The proliferation of textual warning messages in our increasingly technical world has exposed the weaknesses of word signs. Many people are completely or functionally illiterate and cannot read them. But research has shown that the earliest to write about the use of symbols (*e.g.*, Modley, 1966; Mead & Modley, 1968) were overly optimistic in their claims that symbols

could replace written communication. Yet there is still reason to believe that symbols have something important to offer the warnings designer. The research on highway symbols has shown symbols to be generally superior to word signs in terms of legibility, latency to respond and performance under degraded conditions. This research has also generally found symbols to be understandable, or at least easily learnable. However, research in the domain of machinery and automotive applications has shown that context and experience can affect symbol performance. Further, some studies have found effects of age or gender while others have not. Green and Pew's (1978) work along with the research on the use of symbols in public informational signs has demonstrated the need for empirical evaluation of symbols called for by Collins (1982), Mackett-Stout and Dewar (1981) and others. This work has shown that many symbols which were initially judged to be distinct from each other were indeed confusable.

The work of Collins et al. (1982) on the identifiability of warning symbols has found wide variation among different symbols. Apparently, some warning symbols are easily understood while others are not. Studies have not, however, reported any observed effects of age or gender on identifiability. Further, while Friedmann (1988) and Otsubo (1988) have found only marginal effects of pictograms on warning compliance, an important aspect of warning symbol communication has been overlooked. People cannot be expected to comply with warnings, pictorial or otherwise, unless they understand the hazard and how to avoid it. Simply put, it is not sufficient to study the identifiability of warning symbols. Their meaningfulness in terms of hazard information communicated must also be examined.

The Present Research

The present set of studies was designed to evaluate a subset of symbols recommended by the *Westinghouse product safety label handbook* (1981) and the FMC *Product Safety Label System* (1989) for use in warning systems for identifiability, cueing of hazard avoidance knowledge and hazard perception. Though previous studies have tested symbol sets for identifiability or meaningfulness, effects of age and gender have generally not been reported. They are explored here in detail. In Experiment 1 subjects were asked to supply a meaning for 16 symbols. But simple identifiability is not enough to ensure effective symbology. Users must also know what to do to avoid the hazard. Experiment 2, which examines critical knowledge regarding hazard avoidance, was designed to assess what precautionary actions certain symbols bring to mind when presented to subjects. Finally, the last experiment measures several aspects of hazard perception for various situations as described in warning labels. Presence of a pictogram on these labels was manipulated such that conclusions could be drawn regarding the effect that inclusion of pictographic symbols might have on users perceptions of hazard severity and injury likelihood. It was anticipated that the presence of a pictogram might increase perceptions of risk in some cases.

Subjects for all studies came from two sources: psychology courses at the University of Houston and a sample of drivers age 40 and over assembled for a research project on older drivers. The university subjects received credit in an introductory psychology course for their participation and the driving subjects received financial compensation. The University of Houston was chosen to recruit subjects because of the large age range of its students. The subjects from the driving study were selected for that study because they were

all healthy and active drivers. They were ideal for this study because of their wide range of education and because their lifestyles could reasonably be expected to allow them contact with hazardous materials and products displaying warning labels. This subject pool produced a group of subjects with a wide range of experience, age and, especially with regard to the older subjects, education.

Experiment One: Pictogram Identifiability

Introduction

This study was designed to assess relative differences in *identifiability* for a set of pictograms. As used in this context, identifiability refers to the extent to which subjects are able to supply a correct, short definition of the pictogram. Design standards have set identifiability limits for pictogram acceptance. The American National Standards Institute (ANSI) recommends in a draft standard that no pictogram which is identifiable by less than 85% of the target audience be accepted for use (ANSI, 1987). The International Organization for Standardization (ISO) recommends a more pessimistic 67% acceptance criterion (ISO, 1979). The present study evaluates 16 pictograms not only in terms of overall identifiability, but also explores effects of age and gender which are related to identifiability. Through response categorization, common pictogram meaning confusions are also explored.

Pictograms in the present study have been tested with a "worst case" method, because, other than knowing that the test items were warning symbols, subjects were given no context in which to evaluate each pictogram. Further, they were asked to supply a definition after an initial presentation—a method argued against by Easterby (1970). Collins et al. (1982) have argued that pictograms ought to be tested by a context-free method because context adds information and dilutes the test of the pictogram. They argue that there is no single, appropriate context for every pictogram, and there is no reason to believe that all members of the target audience will be attending to context when the pictogram is encountered. With regard to initial presentation tests of identifiability, as opposed to retention tests of studied pictograms, Collins

(1982) argued that the former were more ecologically valid because the general public does not participate in pictogram training programs.

Method

Subjects. Subjects were 148 participants ranging in age from 17 to 83 with a mean age of 35.7 (median=21.5). There were 93 females and 55 males. Ninety-three subjects were under age 40, and 55 subjects were age 40 or over. Figure 1 presents a histogram which details the distribution of subjects' ages.

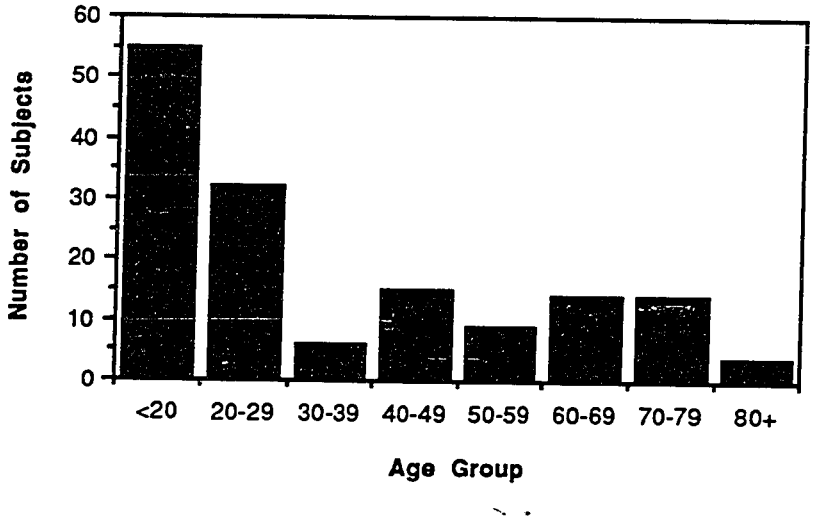

Figure 1: Frequency histogram of Experiment 1 age distribution.

Materials. Sixteen symbols and pictorials recommended for use by the *Westinghouse Product Safety Label Handbook* (Westinghouse Electric Corporation, 1981) were selected for evaluation. The pictograms chosen are noted below and examples of each of these pictograms appear in Appendix A:

Biohazard
Chemical hazard
Ear protection needed
Electricity (3)
Explosive
Eye protection needed
Falling objects
Flammable
Fumes
Hot surface
Laser
Radiation
Rotating machinery (2)

Two different pictograms were used for moving parts and three for electrical hazards, as the *Handbook* recommended more than one for each of these cases. The moving parts pictograms differed in the type of machinery (*i.e.*, rotating gears as opposed to rollers). The electrical hazard pictograms differed in level of abstraction: One showed a simple lightening bolt; a second depicted a lightening bolt shocking a human figure; the last showed a hand being shocked by a wire. The study sought to determine if these graphics were differentially identifiable.

Procedure. Subjects were presented with the 16 pictograms in either of two random orders. For each pictogram, they were asked to describe the hazard that such a symbol or pictogram would be used to warn about. They were given the following instructions:

> On these two pages are pictures which have been taken from warning signs and labels. Next to each one please answer this question:
>
> **What is the picture trying to warn you about?**
>
> For example next to a skull-and-crossbones, you might write "poison."

Because subjects' responses were unconstrained, three raters knowledgeable in the use of pictograms were asked to classify each of the subjects' responses. Through pilot work and other research (Collins et al., 1982), about five categories of potential responses were developed for each pictogram. Subjects' responses to each of the pictograms were transcribed into a Macintosh Hypercard computer program which presented them individually to each rater. A separate screen (or card) was developed for each pictogram. The category names were placed into "buttons" on each card. The program stepped each rater through, in counterbalanced order, each response made by every subject for each pictogram. For each response, raters were

asked to place it into one of the available categories. Categorization was indicated by using a mouse to move the cursor into the appropriate screen button and clicking the mouse button. The program then stored the information and presented the next response for categorization.

Raters received instructions which included the following statements:

> Each of the 16 pictogram cards has several unique categories into which the given response might fit. Refer to the later pages in this manual for specific information about each category. Try to fit each response into a single category and click the corresponding button once to place the response into that category. If you cannot place the item into one category, put it into the first one that is appropriate.
>
> Three other categories appear on all the cards for use as needed. These are (1) "Generic Danger or Warning," (2) "Other," and (3) "No Response." Use Generic Danger or Warning when the subject gave a general response like "Beware" or "Caution" or any other response that could potentially be correct for all of the pictograms. Use the Other category when you cannot fit the response into any other category. And, finally, the No Response category should be used whenever the words "no response" appear on the response line.

A manual giving samples of each pictogram and a description of each category was given to each rater.

Results

To present the results of Experiment 1, several analyses will be described. First, the categorization agreement of the raters will be presented. Having shown the generally strong agreement of the raters, their categorization of subjects' responses will be presented for each pictogram. In this section, each category available to the raters for response classification will be presented in tabular form. Those categories considered a priori correct will be noted as these become the basis for the remaining analyses.

Next, pictogram identifiability will be presented as will sex and age effects. Based on the correctness criteria to be developed in the rater categorization section, the identifiability analyses will present the proportion

of subjects correctly identifying each pictogram. The remaining analyses, sex and age effects, will further break down these proportions as a function of these subject variables. Finally, pictogram confusability will be discussed.

A procedural error gave two groups of subjects the opportunity to refer to an unrelated experimental protocol for assistance while identifying the pictograms used in this study. In the first group, 26 subjects were affected on three pictograms (78 responses). Results from these subjects regarding the hearing protection, laser and fumes pictograms were dropped from the analysis. A different group of subjects was exposed to the eye protection, chemical hazard, rotating gears, and biohazard pictograms. Data from 28 subjects on these four pictograms (112 responses) were discarded.

Rater categorization. Each of the 148 subjects gave a response to each of 16 pictograms which resulted in 2,368 responses for rater categorization. After the 190 responses were dropped due to procedural errors, 2,178 responses were left for categorization by the raters. Overall rater agreement is detailed in Table 1, below:

Table 1: Overall rater categorization agreement.

Number of raters in agreement	Frequency	Percent
0	62	2.8
2	440	20.2
3	1,676	77.0
TOTAL	2,178	100.0

It should be noted that very high agreement was observed among the raters. At least two raters agreed on the categorization of 97.2% of the responses. Each response was categorized based on the responses of the raters. In 77.0% of the cases, the raters were unanimous in their categorization, and in 20.2% of the cases, two of the three raters agreed on a category for the response. In these cases, the modal response was used as the response category. Finally, in only 2.8% of the cases, the raters were in total disagreement regarding the appropriate classification of the response. In these cases, the subject's response was considered unclassifiable and dropped from further analysis. It should be noted that even considering data dropped for lack of rater agreement as well as data discarded for procedural errors discussed above, more than 110 valid observations were collected for each pictogram. Tables detailing rater agreement for each pictogram appear in Appendix B. A detailed presentation of the raters' classification of subjects' responses follows for each pictogram.

Biohazard pictogram. The biohazard pictogram is a specialized pictogram that, with the possible exception of health care workers, is not often encountered. Only one response was dropped from the analysis due to lack of rater agreement. Rater categorization data for this pictogram are presented in Table 2. None of the subjects correctly identified this pictogram with a response that referred to a biological hazard. Common confusions included mechanical hazards such as fan blades or radiation hazards. Responses such as hospital waste and carcinogenic were somewhat correct, but not general enough to appreciate the common usage of this pictogram, so they were considered incorrect.

Table 2: Biohazard pictogram rater categorization

Category	Frequency	Percent
Fan/blades/cutting hazard	8	6.7
Radiation/nuclear hazard	9	7.6
Hospital or other waste	1	0.8
Biohazard / biological hazard*	0	0.0
Chemical hazard	3	2.5
Carcinogenic / causes illness	2	1.7
Other	14	11.8
No response	82	68.9

Note: 1 response was uncategorizable due to lack of rater agreement. Asterisk indicates the response which was considered correct.

Chemical hazard pictogram. The chemical hazard pictogram, which depicts liquid from a test tube being spilled onto a human hand, was often perceived to mean some type of burns or dangerous chemical or skin irritant. All of these responses were considered correct. Seven responses were discarded due to lack of rater agreement. Table 3 presents rater categorization data for this pictogram

Ear protection pictogram. For the wear ear protection pictogram, only four responses were discarded due to lack of rater agreement. Table 4 presents rater categorization statistics for this pictogram. Most subjects (85.4%) gave responses which were placed into categories representing loud noises or wear hearing protection. Responses in these categories were considered correct. As this pictogram was generally well recognized, there were no common confusions.

Table 3: Chemical hazard pictogram rater categorization

Category	Frequency	Percent
Burns*	49	43.4
Acid / corrosive / caustic*	23	20.4
Dangerous or irritant to the skin*	25	22.1
Chemical hazard*	10	8.8
Poison	1	0.9
Other	3	2.7
No response	2	1.8

Note: 7 responses were uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

Table 4: Ear protection pictogram rater categorization

Category	Frequency	Percent
Loud noise / hearing damage*	51	43.2
Wear ear protection*	47	39.8
Brain damage	5	4.2
Be quiet / deaf people	3	2.5
Generic danger or warning	0	0.0
Other	4	3.4
No response	8	6.8

Note: 4 responses were uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

Electrical hazard pictograms. Three pictograms designed to convey an electrical hazard were tested. The categories available to the raters for the classification of the subjects' responses were held constant across these three pictograms. These pictograms differ mainly in the level of abstraction they use to convey their message.

The first electrical hazard pictogram shows only a "lightning" bolt. Rater classification data for this pictogram is presented in Table 5. The modal response to this graphic was, not surprisingly, one mentioning lightning. There were no other common confusions. However, 31.1% of the subjects gave responses which the raters classified as referring to electrical hazards. These responses were considered correct.

Table 5: Electrical hazard pictogram (lightning bolt) rater categorization

Category	Frequency	Percent
Lightning	66	44.6
Electric shock / high voltage*	44	29.7
Electrical lines/wires/cables*	2	1.4
Tripping/slipping hazard	1	0.7
Snakes or insects	0	0.0
Generic danger or warning	5	3.4
Other	6	4.1
No response	24	16.2

Note: Asterisks indicate those responses which were considered correct.

The second electrical hazard pictogram which depicts a bolt of electricity contacting a human figure fared better. Table 6 presents the rater categorization data for this pictogram. About 65% of the subjects gave responses which were placed into one of the electrical hazard categories, while only three subjects gave a response regarding lightning. However, six subjects confused the pictogram for a tripping hazard warning, and two subjects indicated that the graphic referred to an insect hazard of some sort.

The third electrical hazard pictogram depicted an electrical wire shocking a hand. Rater categorization of this pictogram are found in Table 7. About 80% of the subjects gave a response which referred to an electrical hazard. Though this pictogram did not suggest the tripping hazard or lightning hazard confusions to any of the subjects, six subjects responded that it was designed to warn against dangerous insects.

Table 6: Electrical hazard pictogram (wire shocking body) rater categorization

Category	Frequency	Percent
Electric shock / high voltage*	75	52.1
Electrical lines/wires/cables*	18	12.5
Tripping/slipping hazard	6	4.2
Lightning	3	2.1
Snakes or insects	2	1.4
Generic danger or warning	0	0.0
Other	11	7.6
No response	29	20.1

Note: 4 responses were uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

Table 7: Electrical hazard pictogram (wire shocking hand) rater categorization

Category	Frequency	Percent
Electric shock / high voltage*	86	58.5
Electrical lines/wires/cables*	30	20.4
Snakes or insects	6	4.1
Lightning	0	0.0
Tripping/slipping hazard	0	0.0
Generic danger or warning	0	0.0
Other	12	8.2
No response	13	8.8

Note: 1 response was uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

Explosive pictogram. Most subjects (70.3%) indicated that the explosion hazard pictogram referred to some type of explosive hazard. Table 8 details the rater categorization of this pictogram Fourteen subjects (9.5%) confused this pictogram for for a fire hazard pictogram. Because there is a pictogram specifically designed to convey that message, responses of that type were not considered correct.

Eye protection pictogram. With regard to the wear eye protection pictogram, at least two raters were in agreement on all of the responses. No data was discarded for lack of agreement. Table 9 presents categorization data for the eye protection pictogram. About half of the subjects (54.2%) gave responses which were placed into the wear eye protection category. An additional 22.5% of the subjects' responses were classified to indicate that they mentioned some type of eye hazard, but did not mention the need for eye protection. Twelve subjects (10.0%) indicated that the pictogram referred to flying debris. All of these response categories were considered to be correct. While seven (5.8%) subjects mentioned some type of bright light hazard (which could conceivably require the donning of protective eye equipment), responses in this category were not considered correct because the pictogram is not generally used for that type of hazard.

Table 8: Explosive pictogram rater categorization

Category	Frequency	Percent
Explosive*	104	70.3
Fire/burn hazard	14	9.5
Electric shock	3	2.0
Generic danger or warning	1	0.7
Other	7	4.7
No response	19	12.8

Note: Asterisks indicate those responses which were considered correct.

Table 9: Eye protection pictogram rater categorization

Category	Frequency	Percent
Wear eye protection*	65	54.2
Eye hazard (no mention of protection)*	27	22.5
Flying debris, projectiles*	12	10.0
Sun / laser / UV / bright light	7	5.8
Radiation hazard	1	0.8
Other	3	2.5
Generic danger or warning	1	0.8
No response	4	3.3

Note: Asterisks indicate those responses which were considered correct.

Falling objects pictogram. Table 10 presents rater categorization data for the falling objects pictogram. Data for ten subjects were discarded for lack of rater agreement. Fifty-one (37.0%) subjects gave responses which were interpreted to mean that overhead objects could fall. Only responses to this category were considered correct. Common confusions included tripping and falling as well as a low ceiling hazard—34.0% of subjects gave responses which were placed into one of these two categories. Fifteen (10.9%) subjects mentioned specific injuries without detailing how these injuries could occur.

Flammable pictogram. The flammable pictogram depicts tongues of flame and is generally used to indicate a flammable chemical or other fire hazard. No responses to this pictogram were thrown out for lack of rater agreement. Table 11 presents the raters' categorization of responses to this pictogram. Almost all subjects (95.3%) gave responses which mentioned fire, flammability or a burn hazard. Any of these three responses was considered correct. Only one subject confused this pictogram with one for explosive materials.

Table 10: Falling objects pictogram rater categorization

Category	Frequency	Percent
Falling objects*	51	37.0
Low clearance / ceiling, watch head	25	18.1
Tripping / falling / slippery	22	15.9
Miscellaneous specific injuries	15	10.9
Generic danger or warning	3	2.2
Other	7	5.1
No response	15	10.8

Note: 10 responses were uncategorizable due to lack of rater agreement. Asterisk indicates the response which was considered correct.

Table 11: Flammable pictogram rater categorization

Category	Frequency	Percent
Fire*	77	52.0
Fire hazard, flammable*	55	37.2
Burn hazard, hot surface*	9	6.1
Explosive	1	0.7
Generic danger or warning	1	0.7
No response	5	3.4

Note: Asterisks indicate those responses which were considered correct.

Fumes pictogram. The pictogram designed to depict fumes shows a human figure breathing in a cloud of black smokey matter. For this reason, any response which detailed toxic fumes, pollution, smoke or other breathing hazards was considered correct. About 87% of the subjects correctly identified the pictogram using that criterion. Though five subjects (4.5%) responded that the pictogram referred to an ingestion hazard, this incorrect response does not appear to be a common confusion for this pictogram. Table 12 presents the rater categorization data for this pictogram.

Hot surface pictogram. The pictogram designed to warn against hot surfaces successfully communicated a message regarding excessive heat or a burn hazard to 67.6% of the subjects. These responses were considered correct. An additional seven subjects (4.7%) responded that the pictogram was associated with some type of fire hazard. These responses were not considered correct as the pictogram is not used for this purpose. Table 13 presents the rater categorization data for this pictogram.

Table 12: Fumes pictogram rater categorization

Category	Frequency	Percent
Toxic/poisonous fumes*	42	37.5
Smoke / pollution / smog*	18	16.1
Other breathing hazards*	22	19.6
Gas / fumes / vapors*	15	13.4
Harmful if swallowed	5	4.5
Generic danger or warning	1	0.9
Other	6	5.4
No response	3	2.7

Note: 10 responses were uncategorizable due to lack of rater agreement.

Table 13: Hot surface pictogram rater categorization

Category	Frequency	Percent
Hot / heat*	79	53.4
Burns*	21	14.2
Do not touch	8	5.4
Fire / flames	7	4.7
Cutting or other hazard	4	2.7
Other	6	4.1
No response	23	15.5

Note: Asterisks indicate those responses which were considered correct.

Laser pictogram. The laser pictogram depicts a specialized light hazard. Rater categorization of this pictogram is presented in Table 14. Thirty-three subjects (27.5%) gave responses which indicated that they either knew or guessed that the pictogram referred to some type of light hazard, but because this pictogram is used specifically to indicate the presence of a laser light source, only responses which mentioned a laser were considered correct. Only 3 subjects (2.5%) correctly identified this pictogram using this criterion. Common confusions included fire or explosion hazards, radiation hazards and mechanical hazards such as flying particles or projectiles. Two responses were deleted due to lack of rater agreement.

Table 14: Laser pictogram rater categorization

Category	Frequency	Percent
Light hazard (non-laser)	33	27.5
Laser*	3	2.5
Fire / burn / explosion hazard	14	9.5
Radiation / nuclear hazard	7	5.8
Mechanical hazard / projectiles	3	2.5
Other eye hazards	2	1.7
Other	1	0.8
Generic danger or warning	1	0.8
No response	56	46.7

Note: 2 responses were uncategorizable due to lack of rater agreement. Asterisk indicates the response which was considered correct.

Radiation hazard pictogram. The radiation hazard pictogram is similar to the laser and biohazard symbols in that subjects who have not learned its meaning before the testing session were probably unable to guess it when it was presented to them. But more subjects were apparently familiar with the meaning of this pictogram. Table 15 presents the rater categorization data. Eighty-five subjects (57.5%) responded with either a general or specific radiation hazard. Responses of either type were considered correct. Fourteen subjects confused this pictogram with one depicting some type of mechanical hazard, and three subjects responded that it referred to a biological hazard.

Table 15: Radiation pictogram rater categorization

Category	Frequency	Percent
Radiation hazard (general)*	83	56.1
Fan/blades/cutting hazard	14	9.5
Biological hazard	3	1.4
Radiation hazard (specific)*	2	1.3
Civil defense	1	0.7
Other	8	5.4
Generic danger or warning	2	1.4
No response	35	23.5

Note: Asterisks indicate those responses which were considered correct.

Rotating machinery pictograms. Two pictograms designed to convey a rotating machinery (pinch point) hazard were tested. Because the hazards were similar, the categories available to the raters were identical for both of the pictograms.

The rotating gears pictogram which uses a mangled hand caught in machinery to indicate a dangerous pinch point was quite successful at communicating its hazard message to the subjects. Seven responses were dropped from further analysis due to lack of rater categorization agreement. While fewer than 20% of the subjects indicated that the pictogram was warning about moving gears or rotating equipment per se, most subjects (about an additional 55%) indicated hazards associated with injured or caught hands or fingers. All of these responses were considered correct, but responses regarding dangerous machinery were not. Rater categorization data for this pictogram is presented in Table 16.

Table 16: Rotating gears pictogram rater categorization

Category	Frequency	Percent
Other finger/hand injuries*	28	20.3
Keep hands out / watch fingers*	24	17.4
Fingers caught / pinched*	23	16.7
Moving parts / rotation / gears*	23	16.7
Generic dangerous machinery	22	15.9
Other	5	3.6
No response	13	9.4

Note: 7 responses were uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

The rollers pictogram is essentially similar to the rotating gears pictogram except the graphic depicts smooth rollers rather than toothed gears and the hand is oriented differently. Table 17 details rater categorization data

for this pictogram. Though slightly less effective at communicating essentially the same hazard, this pictogram successfully communicated a rotating machinery hazard or a finger/hand injury hazard to about 63% of the subjects. Sixteen responses were considered uncategorizable due to rater disagreement. Again responses which were categorized as generic with regard to some type of generic dangerous machinery were not considered correct.

Table 17: Rollers pictogram rater categorization

Category	Frequency	Percent
Fingers caught / pinched*	28	21.2
Keep hands out / watch fingers*	22	16.7
Other finger/hand injuries*	20	15.2
Moving parts / rotation / gears*	13	9.8
Generic dangerous machinery	13	9.8
Generic danger or warning	3	2.3
Other	4	3.0
No response	29	22.0

Note: 16 responses were uncategorizable due to lack of rater agreement. Asterisks indicate those responses which were considered correct.

Identifiability analysis. Table 18 presents the overall percentage of subjects correctly and incorrectly identifying each pictogram. This table is ordered from the most to the least identifiable pictograms. A subject was judged to have correctly identified a pictogram if the modal response of the raters to that subject's response placed it into a category which was considered correct.

As is apparent from the table, the pictograms selected for this study represent a wide range of identifiability. While the flammable and chemical hazard pictograms were correctly identified by about 95% of the subjects, the laser and biohazard pictograms were identified by almost no one.

Table 18: Percent of subjects correctly identifying each pictogram overall, and by gender and age.

	Percent Correct				
Pictogram	Overall	Females	Males	<40	≥40
Flammable	95.3	94.6	96.4	97.9	90.9
Chemical hazard	94.7	91.7	100.0	95.4	92.3
Wear eye protection	86.7	83.1	93.0	83.9	96.3
Fumes	86.6	81.6	97.2*	84.5	92.9
Wear hearing protection	83.1	80.3	88.1	81.1	89.3
Electrical hazard (hand)	78.9	76.1	83.6	75.0	85.5
Rotating gears	76.1	78.4	71.8	78.4	68.0
Explosive	70.3	61.3	85.5**	76.3	60.0*
Hot surface	67.6	64.5	72.7	75.3	54.6**
Electrical hazard (body)	64.6	62.2	68.5	60.4	71.7
Moving rollers	62.9	56.6	73.5	71.9	44.2**
Radiation	57.4	44.1	80.0***	62.4	49.1
Falling objects	37.0	25.0	55.6***	38.9	33.3
Electrical hazard (bolt)	31.1	31.2	30.9	38.7	18.2**
Laser	2.5	1.3	4.8	1.1	6.9
Biohazard	1.7	2.6	0.0	2.2	0.0

* $p<.05$, ** $p<.01$, *** $p<.001$

Sex effects. Table 18 also presents identification rates for each pictogram by gender. Generally, pictograms were not differentially identifiable for males or females, but there were four apparent exceptions. Using a Yates-corrected chi-squared test, significantly more males than females correctly named the fumes, explosive, radiation and falling objects pictograms. Although these four are the only statistically reliable differences between genders, it should be noted that for ten of the sixteen pictograms tested more males than females supplied the correct identification.

Age effects. Table 18 also presents identification rates for each pictogram by age group. As discussed earlier, for the purpose of this analysis, subjects were divided into an under age 40 group and an age 40 or older group. With a few exceptions, the pictograms tested did not show reliable effects of age on identification rates. Nine of the pictograms were correctly identified by more subjects in the under age 40 group and seven pictograms were correctly named by more subjects in the age 40 and older group. Yates corrected chi-squared tests showed significantly more younger subjects named the explosive, hot surface, moving rollers and lightning bolt electrical hazard pictograms.

Pictogram confusability. There were no noteworthy common confusions for the five most identifiable pictograms: chemical hazard, fumes, flammable and the two protective equipment pictograms. The tongues of flame of the flammable pictogram were confused for an explosive hazard by only one subject. And it should be noted that the black fumes of the fumes pictogram suggested an ingestion rather than an inhalation hazard to five subjects.

The flammable, hot surface and explosive pictograms are related because all concern fire or heat. While 70.3% of the subjects correctly identified the explosive hazard pictogram and 67.6% correctly named the hot surface pictogram, the explosion hazard pictogram was misidentified as a fire or burn hazard pictogram by 16 subjects, and the hot surface pictogram suggested fire or flame to seven subjects. Given the interrelatedness of the messages to be conveyed by these pictograms, these confusions are not considered to be significant detractors from the identifiability of the pictograms.

The electrical hazard pictogram which depicts a wire shocking a hand was correctly identified by 78.9% of the subjects. This was the most readily identifiable of the three electrical hazard pictograms tested; however, six subjects confused it for a snakes or a dangerous insects warning. The electrical hazard pictogram which depicts a wire shocking a human figure was correctly identified by 64.6% of the subjects. Five subjects confused its meaning with either lightning or a snakes/insects warning, and—apparently misled by the angle of the human figure— six thought it referred to a tripping or slipping hazard. The poorest performer of the electrical hazard trio was also the most abstract: Only 31.1% of the subjects correctly identified the pictogram depicting only a "lightning bolt" of electricity. Younger subjects were also more significantly likely to correctly identify this pictogram (38.7% compared to only 18.2%). The modal response (n=66) to this item was that it referred to lightning. While this pictogram might fare better in context, there is reason to consider it too ambiguous for use.

Three of the pictograms were designed to convey motion of some sort: The rotating gears, moving rollers and falling objects pictograms. The

rotating gears pictogram was correctly identified by 76.1% of the subjects, while 62.9% identified the moving rollers pictogram. The most common incorrect response to both of these items was one which ignored the motion component of the hazard and resulted in an answer which referred only to "dangerous machinery" in a generic sense. The moving rollers pictogram was most significantly more likely to be identified by male subjects as well as those under age 40. Only 37.0% of the subjects were able to supply an appropriate meaning for the falling objects pictogram which was often confused for meaning low clearance (n=25) or identifying a tripping or slipping hazard (n=22). This pictogram was significantly more identifiable by male subjects (55.6% correct) than by females (25.0% correct), but by far, unacceptable for general use.

Discussion

The major finding from Experiment 1 is that pictograms are differentially identifiable. Identifiability ranged from an impressive 95% for the flammable pictogram to a poor 1.7% for the biohazard symbol. Only four pictograms—flammable, chemical hazard, eye protection and fumes—were correctly identified by more than 85% of the subjects. Under the guidelines of ANSI Z535.3, only these pictograms should be considered acceptable for general use. The wear hearing protection pictogram also performed quite well, but just below the ANSI acceptability criterion.

Several types of pictogram hazard referents (*e.g.*, heat, motion and electricity) were tested in Experiment 1 allowing some conclusions regarding the relative ease with which these types of referents are communicated symbolically. The pictograms for protective equipment performed very well, but those for the motion- and heat-related hazards (with the exception of the

flammable pictogram) were not so identifiable. None of the motion pictogram made use of arrows and red printing was not available for the heat-related pictograms. It would be interesting to determine the effect of the addition of these graphic elements. With regard to the electrical hazard pictograms, it can be concluded that the level of graphic abstraction is critical to the design of an identifiable pictogram. The graphic which depicts a small bolt of electricity performed much better than did the other pictograms which showed strikingly different levels of detail with regard to the affected body part and the electrical source itself.

Three pictograms, the radiation, laser and biohazard graphics, were symbols whose meanings were not likely to be deduced from an initial encounter with the pictogram. It is generally assumed that the meanings of these pictograms must be learned—in fact, ANSI Z535.1 requires that English meanings always appear with these symbols. They were tested here, though, because it cannot always be assumed that the target audience will be able to read English. Not surprisingly, only 2.5% of the subjects correctly identified the laser pictogram, and only 1.7% identified the biohazard graphic. However, 57.4% of the subjects were able to supply an acceptable meaning for the more commonly encountered radiation symbol. It should be noted that significantly more males (80.0%) than female subjects (44.1%) gave the correct meaning for this pictogram.

Where age or sex differences were observed, they were either in favor of males or the younger subjects or both. It is possible that the younger subjects and the male subjects might be more familiar with technical hazards from training or work experience. For example, the radiation symbol and the explosive pictogram were identified by significantly more males than females.

And the hot surface and moving rollers pictograms were identified by more younger subjects. Perhaps, for whatever reason, males and younger subjects have more knowledge of some of the hazard referents for which pictograms were tested. This is not to suggest that these subjects necessarily have direct experience with these hazards—though some might—only that they are more familiar with them. Or, perhaps, they have more experience at interpreting symbols in general or greater spatial ability. Whatever the case, it must be noted that some demographic subgroups of the target population may be at a disadvantage with regard to pictogram interpretation. For this reason, any evaluation of symbols for general use must include both male and female subjects ranging widely in age.

Seven of the pictograms tested in Experiment 1 were also tested in a similar fashion by Collins et al., (1982). A comparison of the overall percentages of responses judged to be correct are presented in Table 19 for these pictograms. Data from the Collins et al. study are from the "naive" (as opposed to the industrial sample). The Collins et al. researchers also asked subjects to supply short definitions for the pictograms tested, and these responses were scored by three judges. The procedure followed by the judges and the categories available for classification were not the same as in the present research, and this apparently accounts for apparently disparate results on the lightning bolt electrical and radiation hazard pictograms. Collins et al. found many of the same common confusions, but the point here is that differences in pictogram evaluation procedures can occasionally be expected to produce different results. For this reason, as has previously been argued (Collins, 1982; Collins et al., 1982), final pictogram selection should not be based on a single selection procedure, but rather should rely on a variety of

testing methods. It should also be noted that the pattern of results seen in both studies lends support to the notion of Brainard, Campbell & Elkin (1961) that the most readily identifiable pictograms are those that are able to directly represent their referents.

Table 19: Comparison of some Experiment 1 identifiability percentages with Collins et al., 1982 findings

Pictogram	Experiment 1	Collins et al., 1982
Electrical hazard (hand)	78.9	86.9
Electrical hazard (bolt)	31.1	66.1
Explosive	70.3	83.0
Rotating gears	76.1	63.0
Laser	2.5	5.6
Radiation	57.4	30.2
Biohazard	1.7	3.3

Consideration must also be given to the extent to which simple identifiability is sufficient to consider a pictogram meaningful. The identity of the hazard is useful information only if the target audience also has knowledge of how to avoid that hazard. If a readily identifiable pictogram fails to communicate or cue appropriate safety knowledge, it cannot be expected that behavioral compliance to the warning will result. In short, the target audience must understand what the hazard is *and* how to avoid an injury. Experiment 2 uses two methods to evaluate injury avoidance communication for three pictograms.

Experiment Two: Pictogram Meaningfulness

Introduction

If members of the target audience are able to name the referents of a warning symbol, but do not have the knowledge necessary to avoid the hazard, the pictogram is of little use. Simple identifiability as was tested in the first experiment is not sufficient to guaranty a pictogram's utility, Experiment 2 was designed to assess further the hazard information cued by a set of three pictograms. Though design standards and recommendations have been formulated with regard to testing the identifiability of pictograms, no recommendations exist with respect to assessing the *meaningfulness* of pictogram. The present study required subjects to indicate their knowledge regarding these hazards either by completing a behavioral intentions checklist or by producing a list of hazard knowledge and safety behaviors. Lerner and Collins (1980a) found little difference between a multiple-choice and a short answer test of pictogram identifiability, but two assessments methods are used here as pictogram meaningfulness has not been previously studied.

Method

Subjects. There were 133 subjects, 73 females and 60 males. Subjects ranged in age from 17 to 83, with 75 of the subjects under age 40, and 58 age forty or over. Figure 2 presents a histogram of the age distribution for this experiment. They were randomly assigned to one of two groups: hazard checklist or hazard listing. There were 65 subjects in the checklist group with a mean age of 39.4 years. Thirty-six were male, and 39 were under age 40. There were 68 subjects in the listing group, with a mean age of 37.4 years. Twenty-four of the subjects were female, and 36 were under age 40.

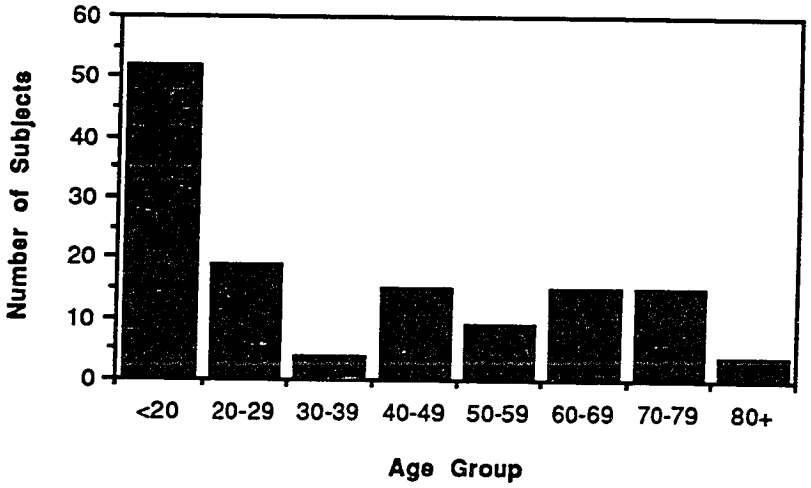

Figure 2: Frequency histogram of Experiment 2 age distribution

Procedure. All subjects were presented with the same three pictograms from the *Westinghouse Product Safety Label Handbook* (1981). Tested were the flammable pictogram, the electrical hazard pictogram which depicts a wire shocking a hand, and the poison pictogram which depicts a skull-and-crossbones. These three pictograms were chosen because of their generally high identifiability and because of the nature of their hazard referents. The electrical hazard and flammable pictograms performed well in Experiment 1 and Collins et al. (1982) found about 80% of their naive (non-industrial) subjects were able to identify the skull-and-crossbones. Finally, each pictogram represents a hazard which can injure in a variety of ways.

Subjects were asked to assume they were preparing to use a product displaying the given symbol. Those in the checklist group were presented with a checklist of 19 precautionary behaviors for each hazard. They were asked to endorse those precautions they would observe if they were preparing to use such a product. Some behaviors were generally good practice for any

product *(e.g., I would look for instructions on the product)* and others were more specific *(e.g., I would not smoke while using it)*. As opposed to checklists, subjects in the listing group were asked to list four potential hazards as well as four precautions that they would take if they were planning to use such a product. Because in listing studies of this type (e.g., Wogalter, Desaulniers & Brelsford, 1987; Donner & Brelsford, 1988) subjects often list variations of the same hazard mode or use overly general statements such as *You could get hurt,* it was decided to ask what was—at least for the purpose of the present study—essentially the same listing question in two ways:

1. List four ways you could get hurt, injured, or killed while using a product that has this symbol on it.

2. List four precautions you would take while using a product that has this symbol on it.

Results

Results are presented first for the checklist group and then for the listing group. Finally, the two procedures are compared.

Hazard checklist. Results for the hazard checklist portion of the experiment are summarized for each pictogram by sex and age. Yates corrected chi-squares were computed for each of the age and sex pairs and significant differences are noted in the tables.

Electrical hazard pictogram. Table 20 presents results for the electrical hazard pictogram. This pictogram seems to suggest several appropriate precautionary behaviors which should be associated with electrical hazards such as not using a device with a frayed cord or exposed wires, or avoiding wet areas during its use. Significantly more females responded that they would not attempt to repair it themselves if it broke compared to the males. This difference was not observed between the age groups. An interesting age

difference was noted: Significantly more subjects under 40 indicated they would look for warnings on the package or product than the 40 and over subjects . It is also interesting to note that though there is no direct hazard of smoking while using an electrical device, 21.9 percent of the females in the sample (compared with none of the males) indicated that they would refrain from smoking while using the hypothetical product.

Poison pictogram. Table 22 presents the findings for the poison pictogram. This item was different from the other items in this study because the skull-and-crossbones was presented along with the word *Poison.* The word was included so that there was no ambiguity regarding the meaning of this symbol, because the checklist items were designed to assess the subjects' knowledge regarding three specific routes of poisoning. It has been claimed that if a manufacturer includes a poison symbol (or simply the words "Poison") on a product, consumers will understand that in addition to the usual route of poisoning via ingestion, poisoning may occur through inhalation of the product's vapors or dermal absorption of the product. The data collected do not fully support this assumption. Not surprisingly, all of the subjects indicated that they would not eat or drink the product, and the overwhelming majority of subjects also indicated that they would not use the product near food preparation areas. Most subjects indicated that they would wash their hands after handling the poison, but significantly fewer of the subjects in the 40 and over age group endorsed this item than in the younger group. Obviously, the concept of the ingestion hazard is understood in principle. Few subjects, however, indicated that they would not smoke while using a poison which is inadvisable because the manual activity might bring the poison into contact with the mouth. Regarding the inhalation hazard,

about half the subjects indicated that they would not use the product in a poorly ventilated room and fewer endorsed the breathing mask item. While these precautionary behaviors may be extreme for some products which display a skull-and-crossbones, they are not overly conservative for many commonly available products such as pesticides. And the data suggest that although some safety behaviors designed to thwart accidental ingestion of a poison do come to mind when subjects are presented with a skull-and-crossbones, appropriate safety behaviors designed to avoid inhalation or dermal absorption of the poison are less likely to be considered. Also, most subjects indicated that they would look for warnings and instructions on the product.

Flammable pictogram. The last pictogram tested in this experiment was the flammable pictogram. Results appear in Table 20. Most subjects indicated that they would look for instructions on the package and more indicated that they would look for warnings. Despite this pictograms' high identifiability in Experiment 1, the concept of avoiding possible sources of ignition was not universal: Most subjects indicated that they would not smoke while using the product, but significantly fewer females and significantly fewer in the age 40 and over group endorsed this item. Further, though the majority of subjects indicated that they would keep the flammable product from sparks or flame, significantly fewer females endorsed this item. Also related to safety with a flammable substance is storing it at a cool temperature. Generally, about half of the subjects endorsed this item, but significantly fewer in the 40 and over group did so. Finally, again, most subjects indicated that they would look for warnings on the product.

Table 20: Electrical hazard pictogram: Percentage of subjects endorsing each item overall and by gender and age group.

	Percent Endorsing				
Item (Each preceded by "I would...")	Overall	Males	Females	<40	≥40
look for instructions on the product.	92.7	97.2	87.5	92.3	93.1
avoid exposed wires.	88.2	88.9	87.5	89.7	86.2
not use it if the cord was frayed.	86.8	86.1	87.5	87.2	86.2
not get it wet.	85.3	88.9	81.3	89.7	79.3
keep it out of reach of children or pets.	82.4	88.9	75.0	89.7	72.4
look for warnings on the product.	80.9	86.1	75.0	94.9	62.1**
look for warnings on the package.	70.6	75.0	65.6	84.6	51.7**
not use it near a swimming pool.	70.6	69.4	71.9	69.2	72.4
not repair it myself if it broke.	44.1	27.8	62.5**	48.7	37.9
keep it away from sparks or flames.	33.8	27.8	40.6	46.2	17.2*
wear protective gloves.	25.0	25.0	25.0	30.7	17.2
not smoke while using it.	10.3	0.0	21.9**	10.5	10.3
wear goggles.	4.4	2.8	6.3	7.7	0.0
store it at a cool temperature.	2.9	2.8	3.1	2.6	3.5
wear ear protection.	1.5	2.8	0.0	0.0	3.5
not use it in a poorly ventilated room.	0.0	0.0	0.0	0.0	0.0
wear a breathing mask.	0.0	0.0	0.0	0.0	0.0
wear a lab coat or protective suit.	0.0	0.0	0.0	0.0	0.0

*$p<.05$, **$p<.01$.

Table 21: Poison pictogram: Percent of subjects endorsing each item overall and by gender and age group.

	Percent Endorsing				
Item ("I would...")	Overall	Males	Females	<40	≥40
keep it out of reach of children or pets.	100.0	100.0	100.0	100.0	100.0
not drink or eat it.	100.0	100.0	100.0	100.0	100.0
look for instructions on the package.	97.1	100.0	93.8	97.4	96.5
store and use it away from food preparation areas.	97.1	100.0	93.8	100.0	93.1
wash my hands after using it.	95.6	97.2	93.8	100.0	89.7*
look for warnings on the package.	94.1	94.4	93.8	92.3	96.6
not store it in an open container.	82.4	80.6	84.4	79.5	86.2
not use it in a poorly ventilated room.	48.5	47.2	50.0	53.9	41.4
wear rubber gloves.	36.8	36.1	37.5	33.3	41.4
not smoke while using it.	32.4	25.0	40.6	38.5	24.1
keep it away from sparks or flames.	27.9	19.4	37.5	33.3	21.0
wear a breathing mask.	23.5	16.7	31.3	28.2	17.2
use it outside.	20.6	11.1	31.3*	23.1	17.2
shower after using it.	16.2	13.9	18.8	20.5	10.3
wear a lab coat or protective suit.	14.7	13.9	15.6	20.5	6.9
store it at a cool temperature.	10.3	2.8	18.8*	18.0	0.0*
wear goggles.	10.3	5.6	15.6	12.8	6.9
wear ear protection.	0.0	0.0	0.0	0.0	0.0

*$p<.05$, **$p<.01$.

Table 22: Flammable pictogram: Percent of subjects endorsing each item overall and by gender and age group.

Item	Percent Endorsing				
	Overall	Males	Females	<40	≥40
keep it out of reach of children or pets.	89.7	94.4	84.4	94.9	82.8
look for warnings on the package.	88.2	94.4	81.3	92.3	82.8
not smoke while using it.	85.3	97.2	71.9**	94.9	72.4*
look for instructions on the package.	83.8	86.1	81.3	82.1	86.2
keep it away from sparks or flames.	82.4	91.7	71.9*	89.7	72.4
not store it in an open container.	72.1	77.8	65.6	74.4	69.0
not drink or eat it.	64.7	61.1	68.8	66.7	62.1
not use it in a poorly ventilated room.	57.4	55.6	59.4	59.0	55.2
store it at a cool temperature.	54.4	52.8	56.3	69.2	34.5**
use it outside.	54.4	55.6	53.1	59.0	48.3
store and use it away from food preparation areas.	42.7	44.4	40.7	48.7	34.5
wash my hands after using it.	38.2	41.7	34.4	33.3	44.8
wear goggles.	17.7	13.9	21.9	28.2	3.5**
wear a lab coat or a protective suit.	13.2	5.6	21.9*	20.5	3.5*
wear rubber gloves.	13.2	11.1	16.6	20.5	3.5*
wear a breathing mask.	7.4	2.8	12.5	7.7	6.9
shower after using it.	4.4	2.8	6.3	7.7	0.0
wear ear protection.	0.0	0.0	0.0	0.0	0.0

*$p<.05$, **$p<.01$.

Hazard listing. The protocols from the hazard listing group were examined in a similar fashion. For each, three appropriate critical knowledge aspects regarding safety were identified and the protocols scored on whether each of these knowledge items was listed or not. For example, for the electrical hazard pictogram each protocol was examined to determine if the subject mentioned that the equipment should not be used if wet or if it had frayed wires, and that the user should not attempt repairs on the equipment. For the poison pictogram, subjects' responses were evaluated to see if they mentioned the ingestion, inhalation and dermal absorption hazards. Finally, for the flammable pictogram, it was determined if a burn hazard, the hazard of explosive vapors, and the necessity of storing the product in a cool place were mentioned. If the subject mentioned a behavior that would be associated with a particular knowledge item, he or she was considered to have expressed the knowledge item. In other words, if a subject indicated he or she would use a poison in a well ventilated area, that subject was considered to understand the inhalation hazard. Responses are presented in Table 23 overall and by sex and age group.

Electrical hazard pictogram. For the electrical hazard pictogram, the results show most subjects realized that water and frayed wiring were hazards associated with electricity, though the numbers were not impressive. A small number of subjects indicated they would not attempt to repair an electrical device themselves. Significantly more males and younger subjects gave this response.

Poison. With regard to the poison pictogram, most subjects knew ingestion of a poison is hazardous, but significantly fewer subjects in the 40 and over group gave this response. Though the difference was only reliable

between the age groups, subjects who listed a dermal absorption hazard tended to be younger and male. More males than females as well as more of the younger subjects indicated that poisoning could occur by inhalation; again, this difference was only reliable between the age groups. This pictogram did not seem to suggest the same hazards to all subjects.

Table 23: Experiment 2 listing group: Percent of subjects indicating each knowledge item by gender and age group.

	Percent Indicating				
Knowledge Item	Overall	Males	Females	<40	≥40
ELECTRICAL HAZARD					
Moisture hazard	72.3	83.3	65.9	80.6	62.1
Frayed wires hazard	55.4	54.2	56.1	61.1	48.3
Repairs hazard	16.9	29.2	9.8*	30.6	0.0**
POISON					
Ingestion hazard	89.2	95.8	85.4	97.2	79.3*
Inhalation hazard	55.4	70.8	46.4	66.7	41.4*
Dermal absorption	66.2	79.2	55.5	80.6	48.3**
FLAMMABLE					
Burn/fire hazard	72.3	75.0	70.7	83.3	58.6*
Explosive vapors hazard	16.9	20.8	14.6	22.2	10.3
Cool storage location	36.9	54.2	26.8*	44.4	27.6

*$p<.05$, **$p<.01$.

Flammable pictogram. Though significantly fewer subjects in the age 40 and over group indicated a burn or fire hazard, the flammable pictogram was generally effective at communicating this hazard. On the other hand,

few subjects indicated that they knew of the explosive vapors hazard and significantly fewer female subjects listed the need to store flammable substances at cool temperatures.

Comparison of procedures. To evaluate the relative utility of the two procedures is is useful to compare each of the nine hazard knowledge items from the listing task with an appropriate item from the checklist procedure. For example, regarding the electrical hazard, 72.3% of the subjects in the listing group listed a hazard associated with water. Given the nature of the two tasks, that fact that 85.3% of the subjects in the checklist group endorsed the statement *I would not get it wet,* does not seem out of line. In other words, both procedures fared about equally well at eliciting knowledge about electrical hazards as they relate to water. Table 24 presents this pairing and others as well as the overall percentages of subjects demonstrating the relevant knowledge. It will be noted that regarding other electrical hazards, the checklist exercise was more likely to elicit knowledge regarding the hazards of frayed wiring or attempting repairs.

Regarding the poison pictogram, the checklist procedure was also more likely to elicit knowledge regarding ingestion hazards and much more likely to allow subjects to express knowledge regarding dermal absorption. However, more subjects mentioned the inhalation hazard in the listing group than in the checklist group.

Finally, similar disparity is seen for knowledge items for the flammable pictogram. The checklist task was more likely to elicit knowledge regarding all of the hazards listed.

Table 24: Percent of listing subjects indicating each knowledge item paired with overall endorsement percentages for a corresponding checklist item.

Listing Item	Listing %	Checklist %	Checklist Item ("I would...")
ELECTRICAL HAZARD			
Moisture hazard	72.3	85.3	not get it wet.
Frayed wires hazard	55.4	86.8	not use it if the cord was frayed.
Repairs hazard	16.9	44.1	not repair it myself if it broke.
POISON			
Ingestion hazard	89.2	100.0	not drink or eat it.
Inhalation hazard	55.4	48.5	not use it in a poorly ventilated room.
Dermal absorption	66.2	95.6	wash my hands after using it.
FLAMMABLE			
Burn/fire hazard	72.3	82.4	keep it from sparks or flame
Explosive vapors hazard	16.9	72.1	not store it in an open container.
Cool storage location	36.9	54.4	store it at a cool temperature.

Discussion

There were differences observed for age and gender for each of the pictograms tested. It can be concluded that none of these three pictograms cued hazard information at uniformly impressive levels for the subjects tested. This finding speaks to the need for testing of pictogram meaningfulness as well as identifiability. With regard to uniformity, subjects may demonstrate general familiarity with a particular type of hazard associated with a given pictogram, but not for other hazards, as with the poison pictogram. Without empirical proof, manufacturers cannot assume

that the addition of a pictogram to a product label communicates information about hazard avoidance, and identifiability alone does not ensure this type of communication. For example, about 95% of the Experiment 1 subjects correctly identified the flammable pictogram, but in this study only about 21% of the listing subjects mentioned the hazard of flammable vapors associated with such products. (Many explosions occur when fumes travelling along the floor of a work area reach an ignition source).

While the two procedures of this experiment were not designed for direct comparison, some discussion of the knowledge gained through each of the procedures is in order. To the extent that hazard information brought to mind from a pictogram alone is different from that cued from the pictogram and the associated checklist, the procedures are different. These procedures both have advantages and disadvantages. Though the checklist procedure is much easier to score and not subject to the criticisms of response classification that the listing task is, the users of consumer products are certainly not presented with checklists in their everyday interactions with these potentially dangerous products. On the other hand it cannot be argued that a request to list hazards can be trusted to elicit a complete set of hazard beliefs and behavioral intentions from any given subject.

Not surprisingly, as seen in Table 24, disparity was often observed between the two procedures. Generally, this disparity favored the checklist procedure. That is, checklist subjects were often more likely to endorse an item than were listing subjects to mention the same concept. This would suggest that knowledge which is present is not brought out by the listing procedure. Further, the checklist serves as an additional cue beyond the pictogram and, thus, dilutes the test of the pictogram. The listing procedure,

then, is a "worst case" test of meaningfulness, but assessment with a variety of methods is recommended.

In addition to the communication of pure hazard information, pictograms can convey other information. The presence of a pictogram in a warning message may communicate more urgency or severity than a textual message alone. A pictogram may increase a users' intentions to comply with a warning or otherwise influence their perceptions of the hazard referent. Experiment 3 was designed to test these notions further.

Experiment Three: Pictogram Use and Hazard Perception

Introduction

This experiment was designed to see in what ways pictograms conveyed messages beyond simple identifiability and hazard avoidance. The argument has been made that the presence of a pictogram in a warning or on a product can alter a user's perceptions of a given hazard by influencing perceptions of injury likelihood or severity. Pictograms may make users more confident in their understanding of the hazard. Or perhaps, a pictogram may increase users intentions to comply with the warning. In Experiment 3, Likert-type response items were designed to measure perceptions such as these.

Method

Subjects. There were 110 subjects (61 females and 49 males) ranging in age from 17 to 83 with an mean age of 42.2 (median=38). Fifty-five subjects were under age 40, and 55 subjects were age 40 or over. Figure 3 presents the distribution of ages.

Materials. A set of eight warning panels was developed incorporating some of the pictograms used in Experiment 1. These warning panels included the signalword *Warning*, a pictogram and a textual message panel in a format which incorporated some of the FMC guidelines for warnings design (FMC, 1989). Additionally, a set of corresponding panels omitting the pictogram was designed. Figure 4 shows an example of a warning panel with a pictogram and Figure 5 presents the corresponding text-only version.

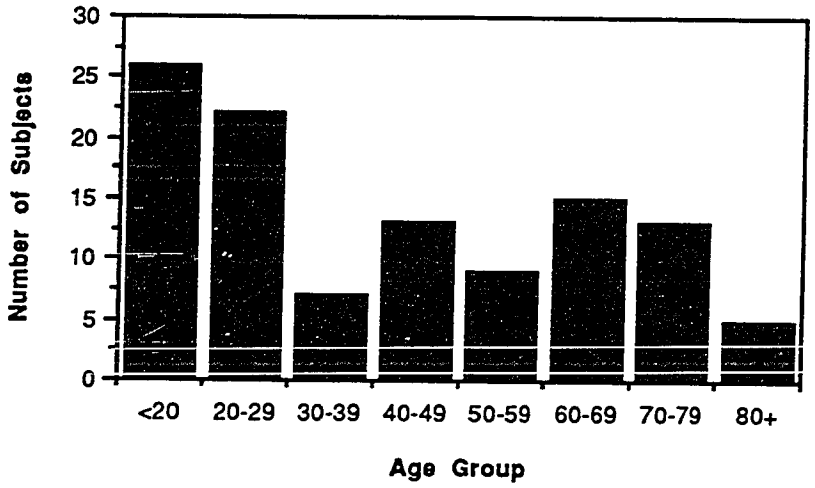

Figure 3: Frequency histogram of Experiment 3 age distribution.

Similar warning panels, both with and without graphics, were designed to incorporate messages appropriate for each of the following eight safety referents:

Biohazard	Fumes
Chemical hazard	Laser
Ear protection needed	Rotating blades
Eye protection needed	Rotating gears

The graphic symbols to be used with the above referents constituted a well-rounded sampling of the types of pictograms in general use. For example, two depict the use of protective equipment. The gears and blades pictograms attempt to convey motion. Injury due to hazardous substances is depicted by the chemical hazard and the fumes pictograms. Finally, the laser and biohazard pictograms are both symbols whose meanings must be learned before they can be identified.

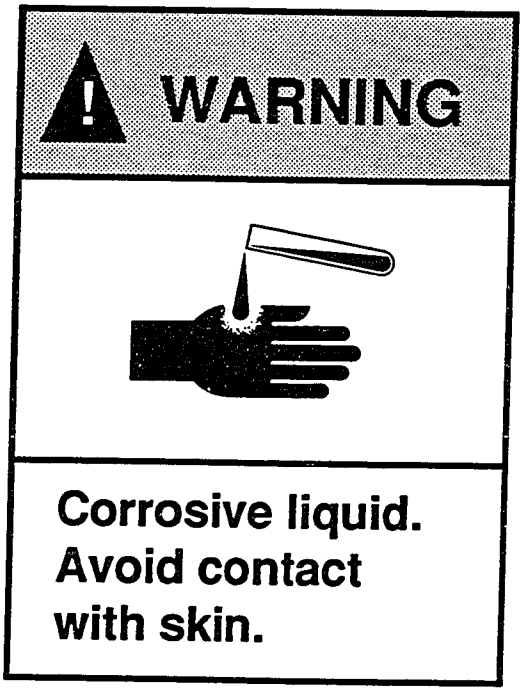

Figure 4: An example of a warning panel with a pictogram used as stimulus material for Experiment 3.

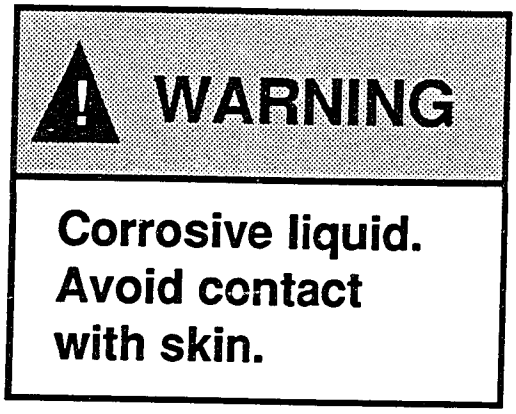

Figure 5: An example of a warning panel without a pictogram used as stimulus material for Experiment 3.

In addition to warning panels appropriate for these eight pictograms, a warning panel was created to simulate an "illiterate" condition: A Russian language warning was developed in an attempt to assess the effect of the addition of a pictogram where it could be reasonably assumed that subjects would be unable to understand the textual message regardless of the presence or absence of the pictogram. The flammable pictogram was selected for use with this message. Examples of all of the stimulus materials used appear in Appendix C.

Procedure. Subjects were presented sequentially with the eight warning messages in a paper-and-pencil protocol. For each warning presentation, subjects saw either the version with a pictogram or the one without. To control for order effects, four different random sequences were created and each subject received the warnings in one of the sequences. For each sequence, four of the warning panels contained a pictogram and four did not. An additional four sequences were created by reversing this situation. In other words, in the second four random sequences, pictograms were used where before they had not been used and vice versa. This allowed a total of eight different random sequences. Finally, to avoid contaminating data collected for the other warning panels, each subject received the Russian language panel last in the protocol. About half received the version with the pictogram and half received the version without.

For each warning panel subjects were asked to respond to the same eight Likert-type response items. They were asked the following questions:

1. How *likely* would you be to comply with this warning?
2. How *hazardous* do you think this situation is?
3. How *gory* is the hazard depicted by this warning?

4. How *clearly* does this warning express its meaning?
5. How *likely* would an injury be to occur?
6. If you were injured, how *painful* might it be?
7. If an *injury* occurred, how severe might it be?
8. How *confident* are you that you understand this hazard?

For each item, subjects were given a nine-point, verbally anchored, Likert-type response scale. The anchor for the low end of the scale was *not at all*, and the anchor at the high end was *very*.

An instruction page which gave general background information for the task as well as specific instructions was attached to the beginning of each packet. Also, for each pictogram subjects received the following instructions:

> Assume that you are using or working around a product or device with this warning on it. Please answer each question by circling the appropriate rating.

Appendix D contains a copy of the instruction page as well as a sample of a page from a protocol.

Results

Though this is a study of the effect of the addition of pictograms to warning presentations, the effect of the individual pictograms are not the focus of the present experiment. Rather, the point of the study was to determine the effect of the addition of pictograms in general. Accordingly, a discussion of the results from these items will be presented first. This discussion will examine each item by exploring the differences observed between subjects who saw the textual warnings alone and with a pictogram. After this discussion, results for each warning message will be examined in more detail in an attempt to assess the effect that the inclusion of a pictogram had on hazard perception as measured by the response items.

Likert-type response item results. Data from the response items were subjected to a multivariate analysis of variance (MANOVA). For each item, an overall effect of pictogram presence was found and these means are reported in Table 25. Collapsing across warnings, the presence of a pictogram elevated the mean response to each response item by a statistically significant amount. Subjects who saw warnings with pictograms gave greater mean responses with regard to their compliance likelihood, situational hazardousness and the likelihood of an injury. Greater differences were found for the injury and understanding items: Subjects who saw the pictograms, gave greater mean responses regarding the goriness of the hazard and the pain and severity of an injury than those who did not. Further, when evaluating warnings with pictograms, subjects gave greater mean responses regarding the clarity of the warning and the confidence with which they understood it. These differences are not large especially when examined by warning, but they do provide information regarding the contribution of a pictogram to hazard perception.

Table 25: Overall mean responses to Likert-type items by pictogram presence.

Item	No Picto	Picto	*p*
1. compliance likelihood	7.5	7.7	<.05
2. hazardousness	7.0	7.4	<.01
3. goriness	4.3	5.3	=.0001
4. meaning clarity	6.1	6.9	=.0001
5. injury likelihood	5.6	5.9	<.05
6. injury pain	6.7	7.2	=.0001
7. injury severity	7.1	7.5	=.0001
8. confidence	6.8	7.2	=.0001

Item 1, compliance likelihood. Obviously the goal of any warning communication is to promote compliance to the hazard avoidance information. Figure 6 presents a line graph of the mean response to this for each warning by pictogram presence. Responses to this item are not impressive with regard to the addition of a pictogram to the warning. The subjects' reported level of intention to comply with the warnings is high and the only significant difference observed was for the Russian language warning. (Response differences found for certain warnings will be discussed later).

Item 2, hazardousness. Subjects were asked about their perceptions of situational hazardousness to determine if the addition of a pictogram could affect that rating. The line graph for this item appears in Figure 7 and shows a

trend in this direction. Once again the only significant difference is for the Russian language warning.

Item 3, goriness. Data for the goriness item are more striking and are presented graphically in Figure 8. A clear trend toward an increased perception of a potentially gory injury is seen with the addition of a visual representation of the hazard to the warning messages. Hazards which can cause generally internal injuries (*i.e.*, the ear protection, laser, biohazard, and fumes warning) do not display this trend so dramatically, and two of the differences are in the opposite direction—though not significant. On the other hand, differences for the eye protection, chemical hazard, blades and gears warnings are significant and indicate the inclusion of a pictogram increases the perception of hazard goriness among subjects. The same is true for the Russian language warning and this difference is also significant.

Item 4, meaning clarity. Subjects were asked about the clarity of the warning to see if warnings with pictograms were perceived to be clearer than with those without. A trend is seen in this regard in Figure 9, but only the differences for the gears and Russian language warning is significant. While the differences are not statistically reliable, it is interesting to note that the eye protection pictogram was apparently perceived to add more to the clarity of its associated warning than was the ear protection pictogram to its warning. Also, the abstract laser and biohazard symbols did not display the trend toward meaning clarity enhancement.

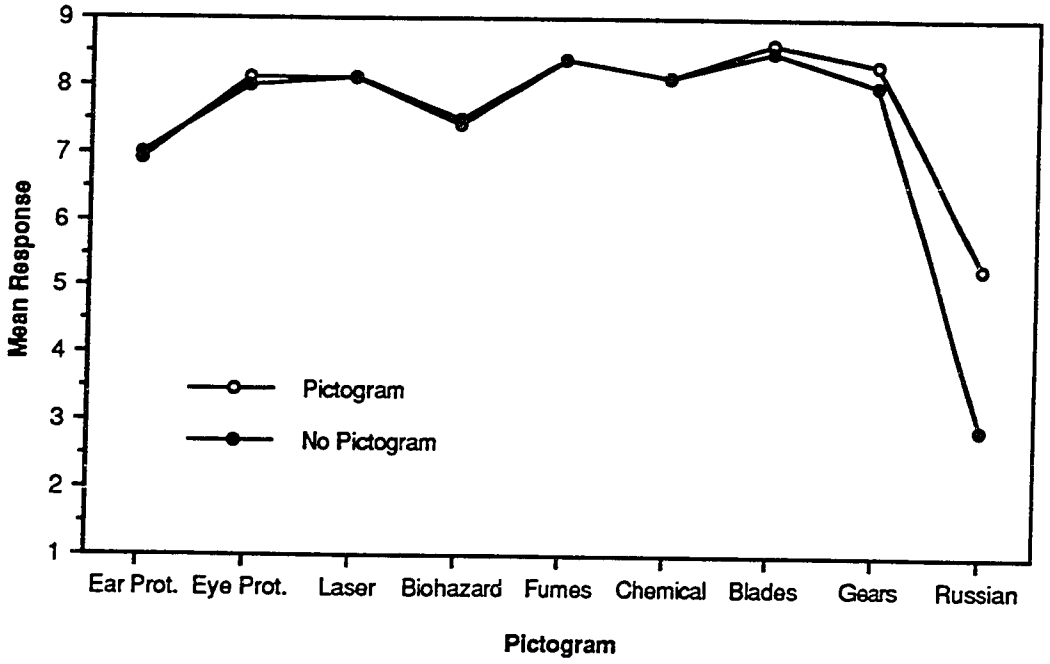

Figure 6: Item 1 (compliance likelihood), line graph of mean scores for all warnings by pictogram presence

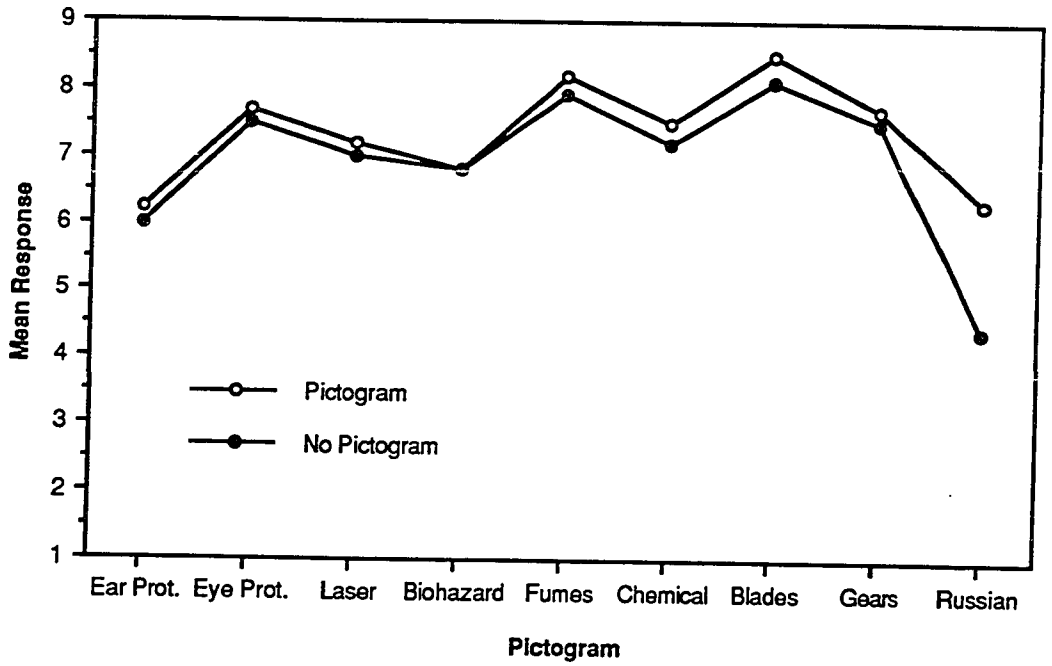

Figure 7: Item 2 (hazardousness), line graph of mean scores for all warnings by pictogram presence

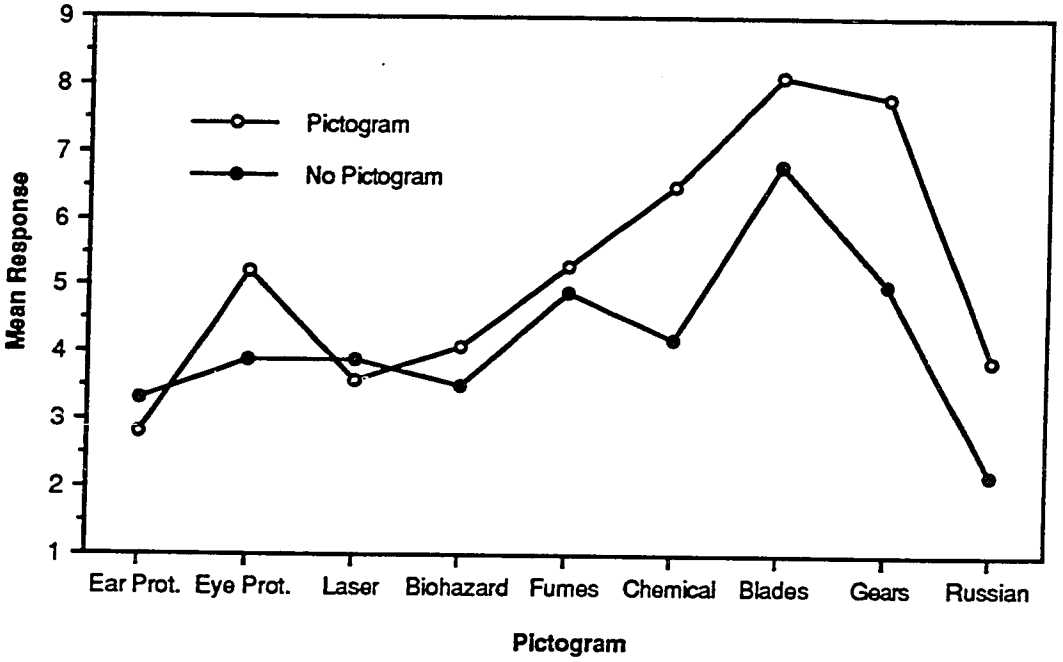

Figure 8: Item 3 (goriness), line graph of mean scores for all warnings by pictogram presence

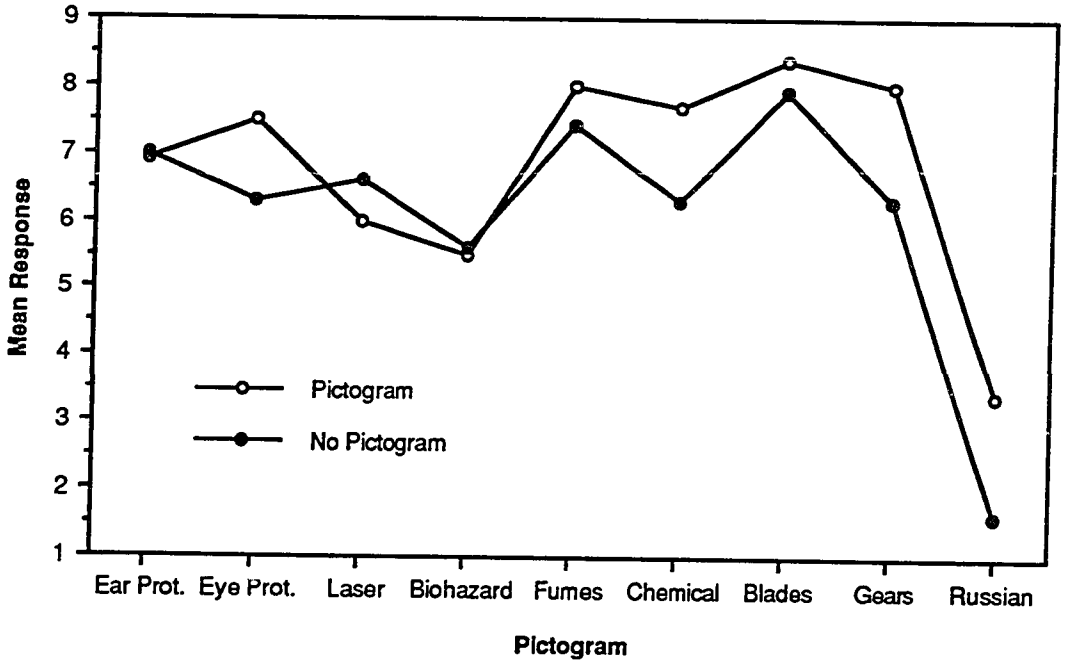

Figure 9: Item 4 (meaning clarity), line graph of mean scores for all warnings by pictogram presence

Item 5, injury likelihood. Subjects were asked about injury likelihood because it was thought that the inclusion of a pictogram in a warning message might increase subjects' perceptions of risk. Though the overall effect is significant (*cf.* Table 25), it is much less apparent from the graph presented in Figure 10. The difference is significant for the eye protection and chemical hazard warning. Subjects who saw these warnings with a pictogram gave greater mean responses to this item indicating increased perceptions regarding the likelihood of an injury.

Item 6, injury pain. Subjects were asked this item with the thought that a visual representation of the hazard might increase subjects perceptions of potential pain should an injury occur. Figure 11 presents the results for this item. Again, Table 25 indicates that the overall difference was significant, but the effect disappears when the analysis is conducted for each warning. The only significant difference is for the Russian language warning.

Item 7, injury severity. This item was related to Item 6, injury pain, but produced somewhat clearer results which are presented in Figure 12. While, once again, the only significant difference is for the Russian language warning, only the biohazard warning displays a difference which does not favor the addition of a pictogram in terms of increasing perceptions of injury severity.

Item 8, understanding confidence. Subjects were asked about their confidence in their understanding of each warning to determine if the inclusion of a pictogram in a warning would influence this rating. A clear trend is seen in this regard in Figure 13. This graph is similar to Figure 9 which presents the data for the meaning clarity item, and significant results are seen for the same warnings: gears and the Russian language warning.

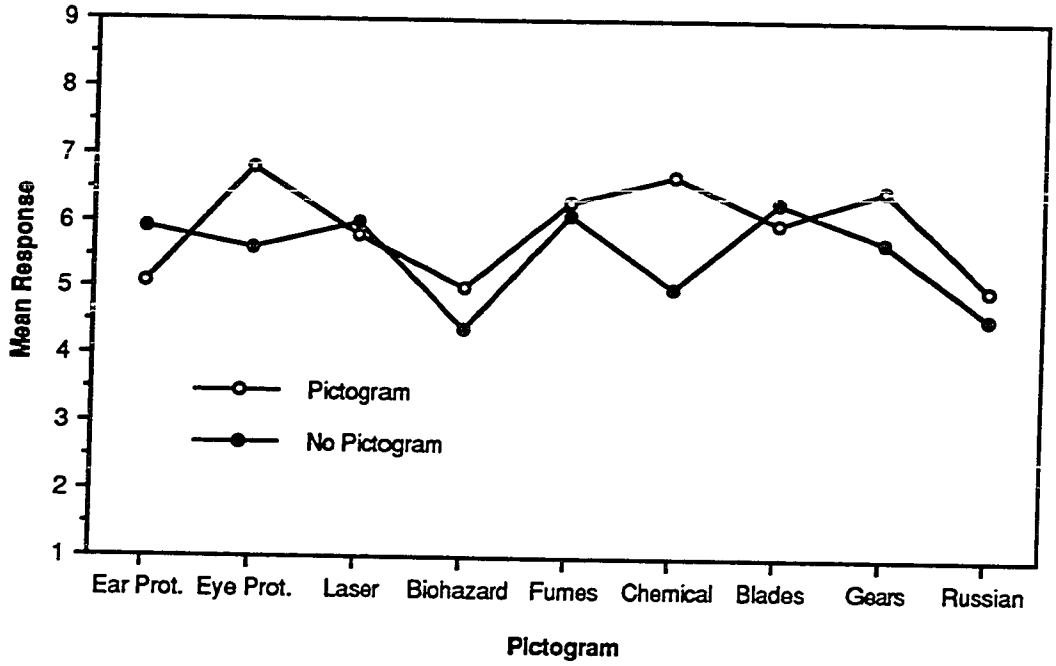

Figure 10: Item 5 (injury likelihood), line graph of mean scores for all warnings by pictogram presence

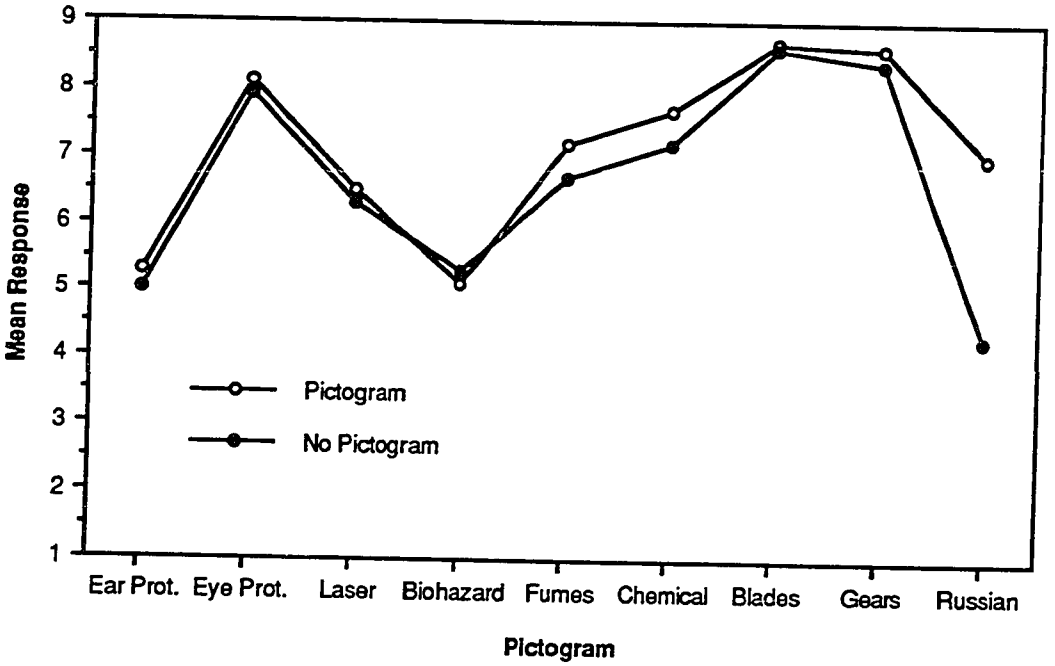

Figure 11: Item 6 (injury pain), line graph of mean scores for all warnings by pictogram presence

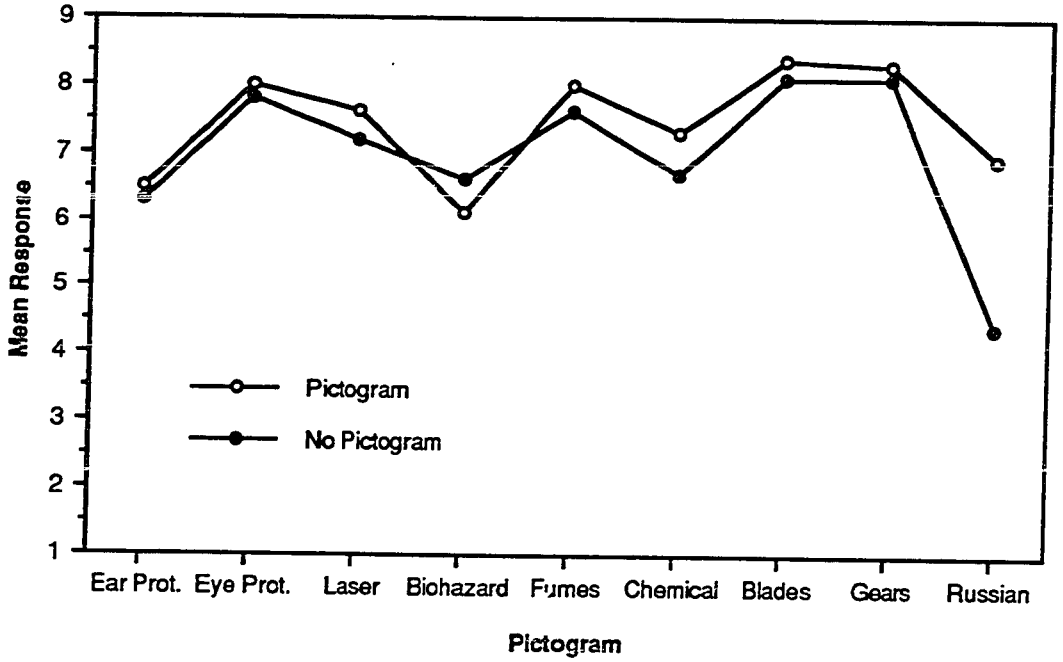

Figure 12: Item 7 (injury pain), line graph of mean scores for all warnings by pictogram presence

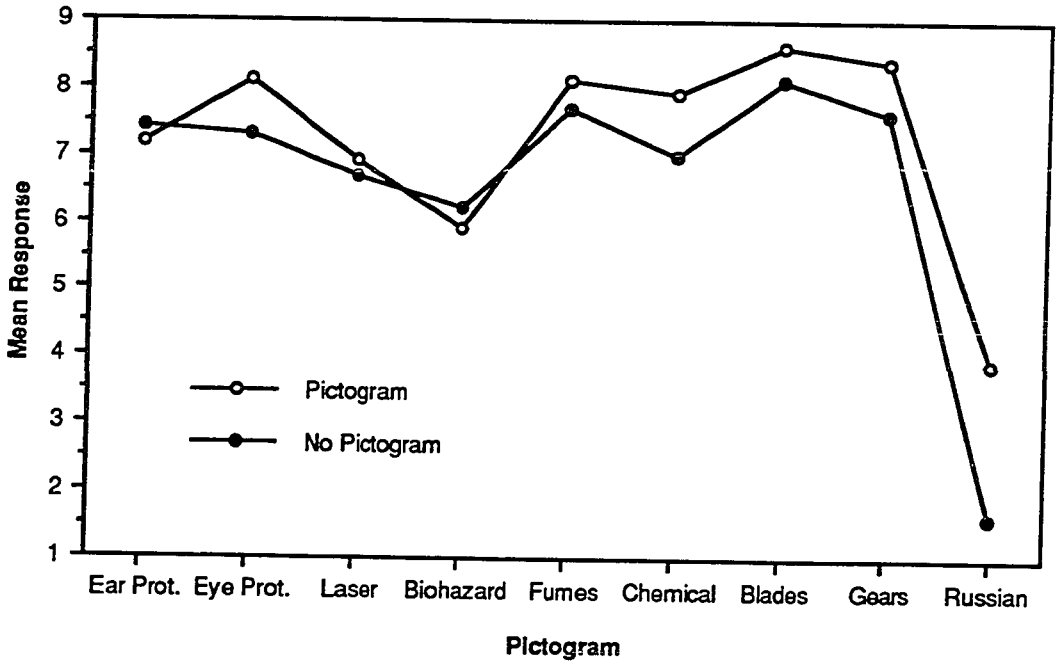

Figure 13: Item 8 (understanding confidence), line graph of mean scores for all warnings by pictogram presence

Detailed results for each warning. This section will present results for each of the hazard referents for which a warning was designed. As the warning messages were not conceptually related, a separate MANOVA using the eight items as dependant variables was performed for each. In addition to the effects of the addition of a pictogram, age and sex effects will be presented. Significant interactions of age or sex with pictogram presence will also be discussed.

Biohazard warning. Table 26 presents the results for this warning. Mean responses are presented by pictogram presence as well as by gender and age group for each item. No significant effect involving pictogram presence was found for this warning. However, regardless of the presence of a pictogram, females and subjects in the 40 or over group considered this hazard to be gorier than did the males or younger subjects. Further, females reported a significantly greater compliance likelihood.

Chemical hazard warning. Table 27 presents results for the chemical hazard warning. While there were no significant main effects of age or gender, there were two effects of pictogram presence. Subjects who saw the pictogram version of the warning rated it significantly gorier than did subjects who saw only the textual version. These subjects also gave a significantly higher injury likelihood rating to the pictogram version of the warning.

Table 26: Biohazard warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	7.5	7.4	7.8	7.1*	7.0	8.0**
2. hazardousness	6.8	6.8	7.2	6.4	6.5	7.2
3. goriness	3.5	4.1	4.3	3.2*	2.9	4.7***
4. meaning clarity	5.6	5.5	6.0	5.1	5.1	6.1
5. injury likelihood	4.4	5.0	4.9	4.5	4.4	5.1
6. injury pain	5.3	5.1	5.2	5.1	4.5	5.8
7. injury severity	6.6	6.1	6.2	6.5	5.7	7.0
8. confidence	6.2	5.9	6.1	6.0	5.6	6.6

*$p<.05$, **$p<.01$, ***$p<.001$

Table 27: Chemical hazard warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.1	8.1	8.1	8.1	7.9	8.4
2. hazardousness	7.2	7.5	7.5	7.3	7.3	7.5
3. goriness	4.2	6.5***	5.4	5.3	4.9	5.8
4. meaning clarity	6.3	7.7	7.0	7.0	7.0	7.1
5. injury likelihood	5.6	6.7**	6.1	6.1	6.2	6.1
6. injury pain	7.2	7.7	7.5	7.3	7.3	7.6
7. injury severity	6.7	7.3	7.1	6.8	6.7	7.3
8. confidence	7.0	7.9	7.3	7.7	7.2	7.7

*$p<.05$, **$p<.01$, ***$p<.001$

Ear protection warning. Table 28 presents results for the ear protection warning. The only significant effects observed for this warning are for the compliance likelihood and hazardousness items. Females gave significantly higher compliance likelihood ratings, as did subjects in the 40 or over group, regardless of the presence of a pictogram. Older subjects also rated this hazard as more hazardous than did younger subjects. Figure 14 presents a significant interaction of pictogram presence with sex which was found for compliance likelihood: The absence of a pictogram led to greater compliance likelihood ratings in females, but when a pictogram was present, the means for the males and females were identical.

Table 28: Ear protection warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	7.0	6.9	7.4	6.5**	6.4	7.5**
2. hazardousness	6.0	6.2	6.1	6.1	5.7	6.6**
3. goriness	3.3	2.8	3.1	3.0	2.4	3.7
4. meaning clarity	7.0	6.9	6.8	7.1	6.7	7.2
5. injury likelihood	5.0	5.1	5.5	5.6	5.2	5.9
6. injury pain	5.0	5.3	5.3	5.0	4.8	5.5
7. injury severity	6.3	6.5	6.3	6.5	6.1	6.7
8. confidence	7.4	7.4	7.3	7.3	7.0	7.7

*$p<.05$, **$p<.01$, ***$p<.001$

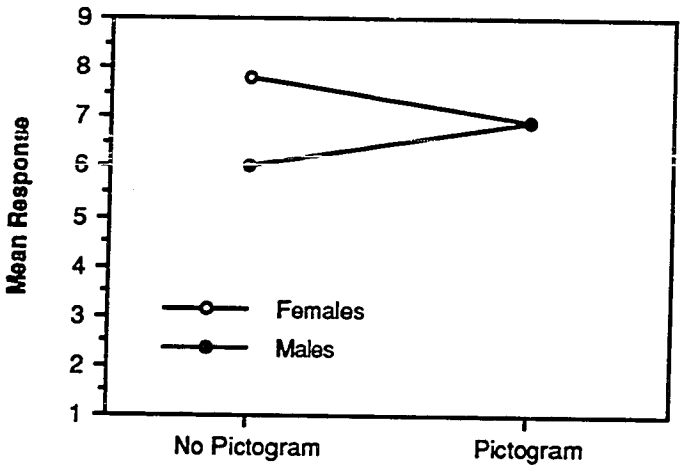

Figure 14: Ear protection warning, plot of interaction of pictogram presence with sex for compliance likelihood.

Eye protection warning. Table 29 presents the detailed results for this warning. There were two significant effects of pictogram presence: Subjects who saw the eye protection warning with a pictogram rated an injury due to a hazard of this type as more gorier and more likely than subjects who saw the textual warning alone. Subjects in the 40 or over group also rated an injury of this type as gorier than did younger subjects regardless of the presence of a pictogram.

Fumes warning. Table 30 presents detailed results for the fumes warning. Though the difference for the meaning clarity item approached significance for the pictogram presence variable, there were no significant main effects or interactions for this warning.

Table 29: Eye protection warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.0	8.1	8.3	7.8	7.8	8.3
2. hazardousness	7.5	7.7	7.9	7.3	7.4	7.9
3. goriness	3.9	5.2*	4.7	4.5	3.9	5.4***
4. meaning clarity	6.3	7.5	7.0	6.9	6.5	7.4
5. injury likelihood	5.6	6.8**	6.3	6.1	5.9	6.5
6. injury pain	7.9	8.1	8.1	7.9	7.9	8.2
7. injury severity	7.8	8.0	7.9	7.9	7.7	8.1
8. confidence	7.3	8.1	7.8	7.6	7.6	7.8

*$p<.05$, **$p<.01$, ***$p<.001$

Table 30: Fumes warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.2	8.4	8.4	8.1	8.2	8.4
2. hazardousness	7.9	8.2	8.2	7.9	8.0	8.1
3. goriness	4.9	5.3	5.2	5.0	4.9	5.3
4. meaning clarity	7.4	8.0	7.8	7.6	7.6	7.8
5. injury likelihood	6.1	6.3	6.1	6.4	5.9	6.6
6. injury pain	6.7	7.2	7.1	6.8	6.5	7.5
7. injury severity	7.6	8.0	7.8	7.7	7.6	8.0
8. confidence	7.7	8.1	8.1	7.7	8.0	7.8

*$p<.05$, **$p<.01$, ***$p<.001$

Laser warning. Results for the laser warning are presented in Table 31. The only main effects for this warning are for age group. Older subjects thought an injury due to a laser hazard was significantly gorier and more severe than did younger subjects. They also felt that the warning was clearer and expressed a greater compliance likelihood. The only significant effect involving the pictogram was an interaction of pictogram presence with gender for the hazardousness item. This interaction is plotted in Figure 15. When no pictogram was present females gave a greater hazardousness rating for this item than did males, but the situation was reversed when a pictogram was present.

Table 31: Laser warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.1	8.1	8.3	7.9	7.6	8.7***
2. hazardousness	7.0	7.2	7.2	6.9	6.4	7.7
3. goriness	3.9	3.6	3.9	3.5	2.9	4.7***
4. meaning clarity	6.6	6.0	6.2	6.5	5.5	7.2**
5. injury likelihood	6.0	5.8	5.9	5.9	5.8	6.0
6. injury pain	6.3	6.5	6.5	6.3	5.9	6.9
7. injury severity	7.2	7.6	7.3	7.6	6.9	7.9**
8. confidence	6.7	6.9	6.5	7.2	6.5	7.2

*$p<.05$, **$p<.01$, ***$p<.001$

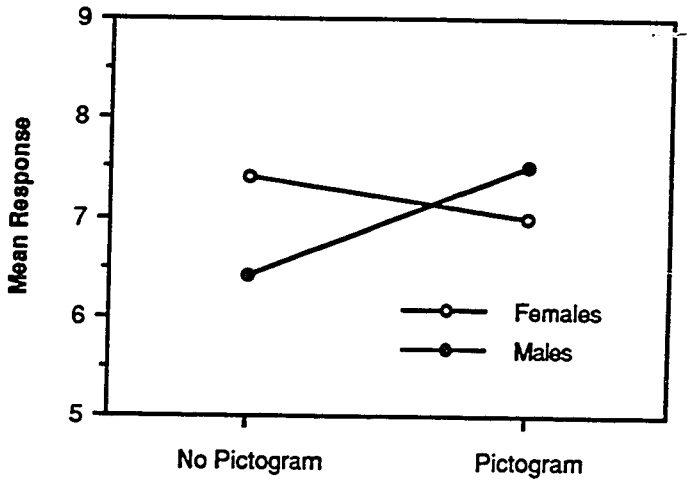

Figure 15: Laser warning, plot of interaction of pictogram presence with sex for hazardousness.

Rotating blades warning. Table 32 presents results for the rotating blades warning. There was a significant main effect for goriness: Females gave significantly greater goriness rating to this hazard than did males regardless of the presence of a pictogram . But, the addition of a pictogram to the warning also resulted in significantly increased goriness ratings. There was also a significant interaction of pictogram with age. Figure 16 presents a graph of this interaction. Pictogram facilitation was observed only for the older subjects—younger subjects responses to this item were not influenced by the presence of a pictogram.

Table 32: Rotating blades warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.5	8.6	8.6	8.5	8.5	8.6
2. hazardousness	8.1	8.5	8.3	8.3	8.5	8.1
3. goriness	6.8	8.1**	7.8	6.9*	7.2	7.7
4. meaning clarity	7.9	8.4	8.1	8.3	8.2	8.1
5. injury likelihood	6.3	6.0	5.9	6.4	6.1	6.1
6. injury pain	8.6	8.7	8.6	8.7	8.7	8.6
7. injury severity	8.1	8.4	8.2	8.2	8.0	8.4
8. confidence	8.1	8.3	8.3	8.4	8.4	8.4

*$p<.05$, **$p<.01$, ***$p<.001$

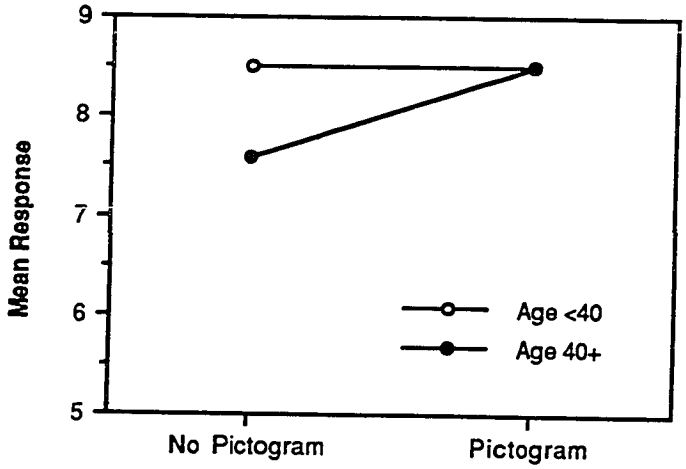

Figure 16: Rotating blades warning, plot of interaction of pictogram presence with age group for hazardousness.

Rotating gears warning. Table 33 presents results for the rotating gears warning. A significant main effect of age group was found for the goriness item: Older subjects gave greater responses to this item than did the younger subjects. As with the rotating blades warning, there was also a significant effect of pictogram presence for this item. Subjects who saw the pictogram version of the warning gave greater responses to the goriness item. There was also a significant effect of pictogram presence for the meaning clarity item. Subjects who saw the rotating gears warning with the pictogram reported the meaning of the warning to be significantly clearer than did subjects who saw only the textual version.

Table 33: Rotating gears warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	8.0	8.3	8.3	7.9	8.0	8.4
2. hazardousness	7.5	7.7	7.9	7.3	7.6	7.6
3. goriness	5.0	7.8***	6.6	6.2	5.7	7.2***
4. meaning clarity	6.3	8.0***	7.1	7.2	6.9	7.4
5. injury likelihood	5.7	6.5	6.0	6.2	6.0	6.1
6. injury pain	8.4	8.6	8.5	8.5	8.5	8.6
7. injury severity	8.1	8.3	8.2	8.1	8.1	8.3
8. confidence	7.6	8.4*	7.9	8.1	7.9	8.1

*$p<.05$, **$p<.01$, ***$p<.001$

There were two interactions with pictogram presence found for the rotating gears warning. Figure 17 presents a plot of the interaction of pictogram presence with goriness: Based on the textual warning, older subjects perceived the hazard to be gorier than did younger subjects. But, the addition of a pictogram resulted in increased perceptions of goriness for both groups. Figure 18 presents the interaction of pictogram presence with gender for meaning clarity: Males perceived the textual warning to be clearer then did females, but this was reversed when a pictogram was present. Perhaps the males did not need the pictogram in this case.

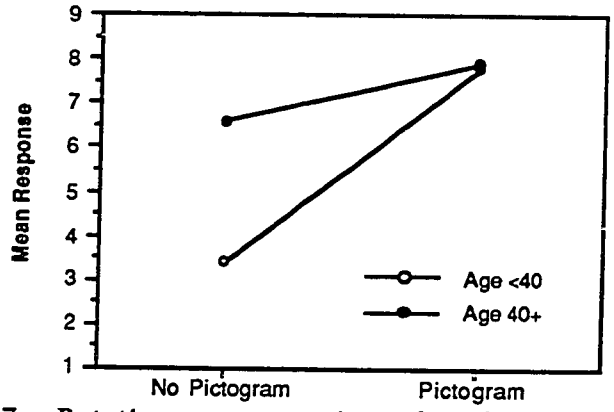

Figure 17: Rotating gears warning, plot of interaction of pictogram presence with age group for goriness.

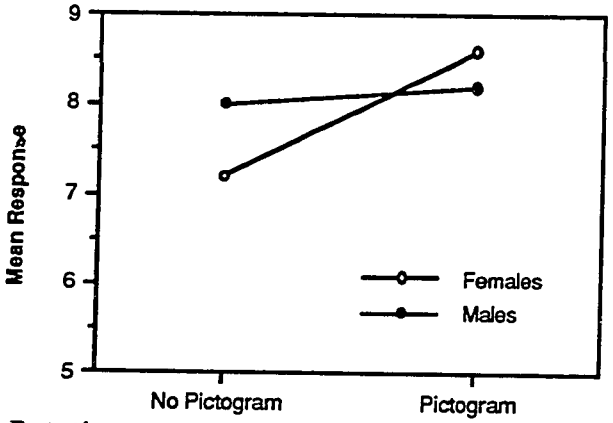

Figure 18: Rotating gears warning, plot of interaction of pictogram presence with sex for understanding confidence.

Russian language warning. Two subjects who had experience with the Cyrillic alphabet through Russian language coursework were excluded from the analysis of this warning. Table 34 presents the results for this warning. There were two main effects of age group. Subjects in the 40 or over group rated hazard as gorier than did younger subjects. They also reported a significantly greater compliance likelihood. Not surprisingly, the addition of a pictogram to the otherwise uninterpretable Russian language warning resulted in several significant main effects of pictogram presence. Subjects who saw the pictogram version of the warning gave greater injury pain and severity—but not likelihood—ratings than those who saw the text only version. Subjects rated the situation as more hazardous and gorier and rated the warning as clearer when the pictogram was present. They also reported greater confidence in their understanding of the hazard and a higher compliance likelihood.

Table 34: Russian language warning: Mean responses by pictogram presence, sex and age group.

	Picto Presence		Sex		Age	
Item	No Picto	Picto	Female	Male	<40	≥40
1. compliance likelihood	2.9	5.3**	4.0	4.6	3.5	5.3*
2. hazardousness	4.4	6.3*	5.3	5.8	5.1	6.0
3. goriness	2.2	3.9*	3.0	3.5	2.7	3.9*
4. meaning clarity	1.6	3.4**	2.0	3.4*	2.2	3.3
5. injury likelihood	4.6	5.0	5.0	4.6	4.8	4.9
6. injury pain	4.3	7.0***	5.7	6.1	5.6	6.3
7. injury severity	4.4	6.9***	5.6	6.2	5.6	6.3
8. confidence	1.6	3.9***	2.5	3.5	2.5	3.5

*$p<.05$, **$p<.01$, ***$p<.001$

Discussion

Overall, the addition of a pictogram to a warning panel resulted in greater mean responses to all of the eight response items. Subjects who saw warnings with pictograms indicated higher compliance likelihood, situational hazardousness and likelihood of an injury. Differences were found for the injury and understanding items as well. Also, warnings with pictograms led to higher responses regarding clarity of the warning and the confidence with which they understood it.

Some of the warning panels tested referred to internal hazards while others referred to hazards of an external nature. The internal hazard referents were biohazard, hearing protection, fumes and laser; the external

referents were chemical hazard, eye protection and rotating blades and gears. No main effects of pictogram presence were observed on any of the response items for any of the internal hazard referents. On the other hand, main effects of pictogram presence were observed for the goriness item on all of the external hazards. It is possible that in addition to gorier, the use of a pictogram in some way makes an external, easily pictured hazard more concrete. Future work might explore this item more closely by relating it hazard believability and locus of control measures.

Of the warning panels tested, the Russian language warning message produced the greatest effects of pictogram presence. Significant main effects were observed for all response items except injury likelihood. When subjects viewed the otherwise uninterpretable message, the inclusion of the flammable pictogram increased many of their perceptions of the hazard. Thus, there is reason to believe that when a pictogram is used in a textual warning message which is in a language foreign to members of the target population, there will be some beneficial effect. The performance of the flammable pictogram in the first two studies suggests that users would not be fully equipped to avoid injury from the hazard if all they could understand was the pictogram, but they would perceive the hazard to be greater and more severe.

From the overall item analysis, it can be concluded that the inclusion of a pictogram elevates subjects' perceptions with regard to the eight items tested. With a pictogram in a warning message, users report that they perceive the situation to be more hazardous, that an injury is more likely, and that they are more likely to comply. This effect is more pronounced for perceptions of goriness, injury severity and pain as well as meaning clarity

and confidence in understanding the warning. But effects of this type are not seen uniformly for each warning tested, and it only occurred for warning messages which referred to the more easily represented, external hazards. Future research might employ a policy capturing methodology to compare pictograms for the same referent in an attempt to isolate the aspects of pictogram design which relate to the elevation of hazard perception. For example, it would be interesting to know if depiction of the injury agent as opposed to an inflicted injury is more effective at increasing hazard perceptions. It would also be useful to learn the extent to which behavioral compliance is related to hazard perception.

General Discussion

Because of the wide range of identifiability seen in Experiment 1, it is clear that empirical target audience validation of pictograms is an essential part of the warnings design process. Warnings designers cannot rely on intuition or graphic design principles alone to produce effective pictograms. Further, the range of identifiability suggests that studies which evaluate the effectiveness of pictograms using only one or two symbols may only be thought of as a test of those pictograms, not as a test of pictograms in general. The results from Experiment 2 showed that different testing methods can lead to different results and conclusions regarding the utility of specific pictograms. It is recommended that more than one method of evaluation be employed in pictogram validation studies, especially where pictogram meaningfulness is concerned. This recommendation is consistent with the recommendations of Collins (1982) and others who caution that different techniques may lead to different results. Finally, gender and age differences observed in the first two experiments underscore the need for a assessment sample that adequately represents the anticipated target audience.

The results from Experiment 3 show that pictograms used in warnings can affect users' perceptions of the hazard referent. Where external, easily represented hazards are concerned, pictograms contribute to increased perceptions of hazard. That the results show that pictograms do not uniformly intensify hazard perception suggests that some hazards lend themselves more easily to effective graphic representation. When such is the case, it can be expected that the use of a pictogram in a warning message will communicate hazard information beyond the hazard identity to members of

the target audience. Further, users who are unable to read a textual warning will benefit in terms of elevated hazard perceptions if a pictogram is added to a warning.

The present work has shown that all pictograms are not created equal: Some are more easily identified; some communicate or cue more information regarding hazard avoidance and, some affect hazard perception more than others. Though imaginative research can probably reveal redeeming qualities about even poor pictograms, the present studies support the calls of Easterby (1970), Collins (1982) and Zwaga (1989) for empirical evaluation of pictograms. Also, they speak to the need for evaluation of more than simple identifiability. Pictogram perception is a complex phenomenon and must be approached as such.

Pictogram researchers and designers should endeavor to find those aspects of pictogram design which maximize not only identifiability, but also meaningfulness and the degree to which pictograms increase users' perceptions in other relevant ways with regard to the hazard referent. There are many strategies to pictogram construction which may reasonably be expected to contribute—or detract from—pictogram perception. For example, Friedmann (1988) has identified proactive and reactive pictograms, Dewar (1976) has shown that positive messages are easier to communicate graphically, and Experiment 1 demonstrated the importance of level of abstraction with regard to identifiability. A well designed stimulus set which would include these and other dimensions could be studied in the context of a multidimensional scaling paradigm or policy capturing analysis to enhance the present understanding of what kinds of pictogram components are most useful. Research by Laughery and Stanush (1988) has shown an effect of

explicitness with regard to textual warnings and the results from Experiment 3 suggest that a similar effect could be found for pictograms. It is possible that explicit, reactive pictograms—those which depict a graphic injury, or are otherwise shocking and unusual—influence users' hazard perceptions in more dramatic ways than proactive and less striking pictograms and thus might be more effective at hazard communication. Explicit pictograms may concretize the hazard for the user and might also affect hazard believability—the extent to which users accept the reality of the hazard and the likelihood of an injury. For that matter, the extent to which a pictogram, whether explicit or not, has attentional qualities which motivate the user to read or comply with warnings which would have otherwise gone unnoticed has yet to be fully explored, though Young and Wogalter (1988) have shown that instruction manual warnings are better remembered if pictograms were present.

Because the present work revealed few general trends which were consistently observed across pictograms, researchers should also concentrate on improving and broadening pictogram evaluation techniques. Regardless of developments in the understanding of pictogram communication, there remains the need for empirical validation of specific pictograms and current techniques are somewhat unsophisticated. Zwaga (1989) has begun to explore the evaluation process and it is hoped that others will follow. This is probably the only kind exploration of pictogram evaluation procedures to have been conducted, and researchers have yet to explore the extent to which pictogram identifiability can be reliably measured by multiple choice and short definition procedures. Zwaga's notion of requiring subjects to supply

more than just a meaning for each pictogram under study is a promising technique and there room for further improvement in this area.

Increasing language barriers due to functional illiteracy and the need for increasingly technical hazard information have rendered textual warnings useless to a significant segment of the population. Early proponents of the use of symbols suggested that written language could be replaced by a more universal, graphically-oriented language system. Research has tempered this enthusiasm, but shown symbols to be of high utility in several domains. And, though they are not well suited to all applications, there is every reason to believe that graphic symbols represent an important communication tool for the warnings designer as well.

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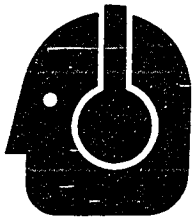
Appendix A: Stimuli used in Experiment 1

Biohazard

Chemical hazard



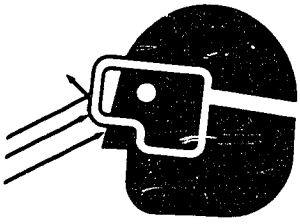
Ear protection needed

Electrical Hazard (1)

Electrical Hazard (2)

Electrical Hazard (3)

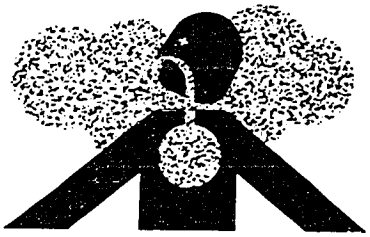
Explosive



Eye Protection Needed

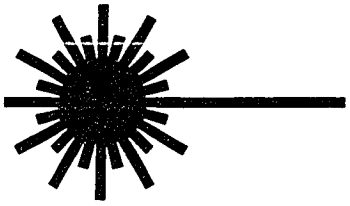
Falling objects

Flammable



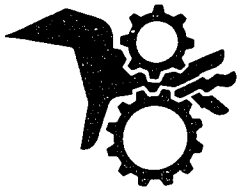
Fumes

Hot surface

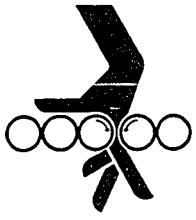


Laser

Radiation



Rotating Gears



Moving Rollers

Appendix B: Rater agreement tables by pictogram for Experiment 1

Table B1: Biohazard pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	2	1.4
2	8	5.4
3	138	93.2

Table B2: Chemical hazard pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	7	4.7
2	60	40.5
3	81	54.7

Table B3: Ear protection pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	5	3.4
2	22	14.9
3	121	81.8

Table B4: Electrical hazard (lightning bolt) pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	0	0.0
2	13	8.8
3	135	91.2

Table B5: Electrical hazard (wire shocking body) pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	4	2.7
2	26	17.6
3	118	79.7

Table B6: Electrical hazard (wire shocking hand) pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	1	0.7
2	46	31.1
3	101	68.2

Table B7: Explosive pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	0	0.0
2	8	5.4
3	140	94.6

Table B8: Eye protection pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	1	0.7
2	31	20.9
3	116	78.4

Table B9: Falling objects pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	10	6.8
2	29	19.6
3	109	73.6

Table B10: Flammable pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	0	0.0
2	32	21.6
3	116	78.4

Table B11 Fumes pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	13	8.8
2	55	37.2
3	80	54.1

Table B12: Hot surface pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	0	0.0
2	19	12.8
3	129	87.2

Table B13: Laser pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	2	1.4
2	20	13.5
3	126	85.1

Table 14: Radiation pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	0	0.0
2	12	8.1
3	136	91.9

Table B15: Rotating gears pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	11	7.4
2	42	28.2
3	95	64.2

Table B16: Rollers pictogram rater categorization agreement

Number of raters in agreement	Frequency	Percent
0	16	10.8
2	46	31.1
3	86	58.1

Appendix C: Stimuli used in Experiment 3

WARNING

Biohazard.
Hospital waste.
Dispose of in
properly marked
containers.

WARNING

Corrosive liquid.
Avoid contact
with skin.

WARNING

Biohazard.
Hospital waste.
Dispose of in
properly marked
containers.

WARNING

Corrosive liquid.
Avoid contact
with skin.

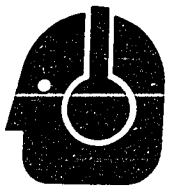
WARNING

Loud noise.
May damage
hearing. Wear
ear protection.

WARNING

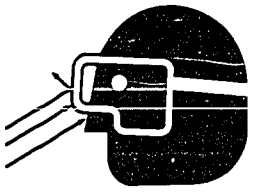
Flying particles.
Eye Hazard.
Wear eye
protection.

WARNING



Loud noise.
May damage
hearing. Wear
ear protection.

WARNING



Flying particles.
Eye Hazard.
Wear eye
protection.

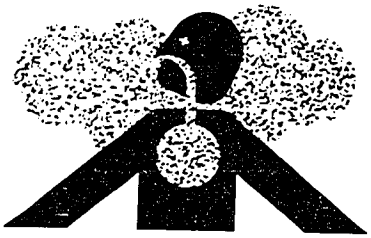
WARNING

Toxic fumes. Can damage lungs. Wear respirator.

WARNING

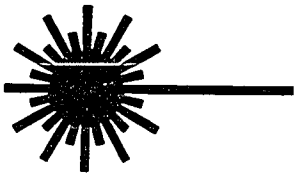
Laser. Do not stare directly into beam. Wear eye protection.

WARNING



Toxic fumes. Can damage lungs. Wear respirator.

WARNING



Laser. Do not stare directly into beam. Wear eye protection.

WARNING

Sharp blades.
May cut fingers
off. Keep clear.

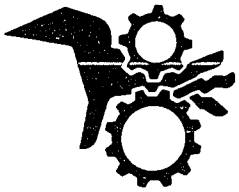
WARNING

Rotating gears.
May catch
fingers Keep
clear.

WARNING

Sharp blades.
May cut fingers
off. Keep clear.

WARNING



Rotating gears.
May catch
fingers Keep
clear.

Опасность

Туалетом не пользоваться, когда поезд стоит.

Опасность

Туалетом не пользоваться, когда поезд стоит.

Appendix D: Instructions used in Experiment 3 and a sample protocol page

Instructions

Thanks for agreeing to participate in this phase of the experiment.

Please circle your sex and write in your age:

Sex: M F **Age: _____**

Also, please list all of the **foreign languages** that your speak or have had any courses in, no matter how long ago: _____

_____

You are about to read several warning labels that could actually be found in factories and other workplaces around the city. After each warning there are several questions like these:

1. How *likely* would you be to comply with this warning?

not at all 1 2 3 4 5 6 7 8 9 very likely

2. How *hazardous* do you think this situation is?

not at all 1 2 3 4 5 6 7 8 9 very hazardous

Please answer each of these questions as best as you can. Just circle the number that best indicates your response. **Please don't circle more than one number, and please try to answer each question.**

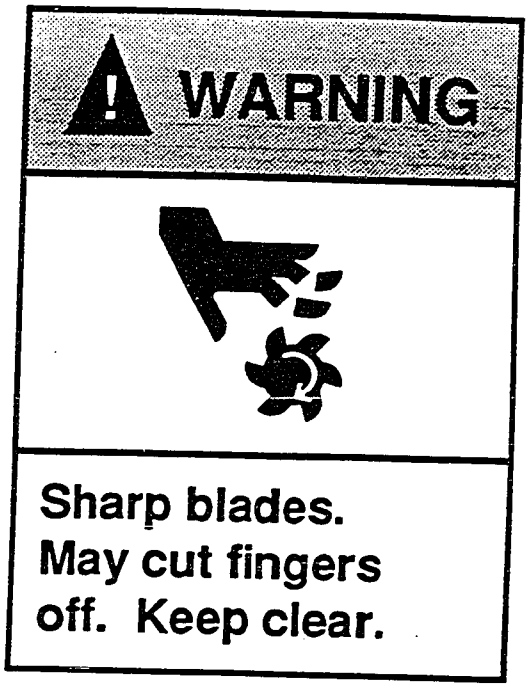
Keep in mind that many of the hazards depicted in the warning labels are serious. Most are of the type of dangers faced by factory or construction workers. In other words, it would be very easy to rate all of them as "very hazardous" or "very dangerous."

If you start out by circling "8" or "9" for the first one or two warning labels, you might find that later you want to use an even higher number for an even more dangerous hazard. With that in mind, here is a list of the hazards that are included in the packet:

Corrosive Chemical — Avoid contact with skin.
Flying particles — Eye hazard.
Laser — Do not stare directly into beam.
Loud noise — Can damage hearing.
Biohazard — Hospital waste.
Rotating gears — May catch fingers.
Sharp blades — May cut fingers off.
Toxic fumes — Can damage lungs.

Please begin. **If you have any questions, feel free to ask them.**

Assume that you are using or working around a product or device with this warning on it. Please answer each question by circling the appropriate rating.



1. How *likely* would you be to comply with this warning?

not at all 1 2 3 4 5 6 7 8 9 very likely

2. How *hazardous* do you think this situation is?

not at all 1 2 3 4 5 6 7 8 9 very hazardous

3. How *gory* is the hazard depicted by this warning?

not at all 1 2 3 4 5 6 7 8 9 very gory

4. How *clearly* does this warning express its meaning?

not at all 1 2 3 4 5 6 7 8 9 very clearly

5. How *likely* would an injury be to occur?

not at all 1 2 3 4 5 6 7 8 9 very likely

6. If you were injured, how *painful* might it be?

not at all 1 2 3 4 5 6 7 8 9 very painful

7. If an injury occurred, how *severe* might it be?

not at all 1 2 3 4 5 6 7 8 9 very severe

8. How *confident* are you that you understand this hazard?

not at all 1 2 3 4 5 6 7 8 9 very confident