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Symbols for Industrial Safety

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
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ABSTRACT

Written signs are commonly used in industrial sites to provide hazard warnings and safety information. The use of safety symbols may increase the effectiveness of safety communication, because such signs are language-free, and because they can be recognized more rapidly and accurately than written text even under some conditions of interference and distraction. The effectiveness of safety symbols critically depends upon the selection of symbolic images which are readily understandable to the intended audience. A four phase evaluation of a set of selected industrial worksite symbols is described. The four phases involved identification of 33 key safety messages, selection of candidate symbols for each message, evaluation of the understandability of the candidate symbols, and determination of the preference for the 87 candidate images, using both industrial and nonindustrial (naive) personnel.

Symbol understandability, in terms of percentage of correct responses and confusions, varied widely for the thirty-three referents. Despite standardized use for a number of years, the radiation, biohazard, and laser symbols were frequently misidentified. Symbols for protective gear, first aid, and emergency equipment were generally correctly identified. The different images selected for various hazards show the greatest range in understandability, with the results for symbolic versions of entanglement, electricity, corrosion, and overhead hazard being quite different. The preference data generally support the understandability data, with the most correctly identified image usually being the most preferred image. Participants also provided insightful comments about the reasons for their choices, including ideas about the visibility, representativeness, and effectiveness of the images proposed for each referent.

Key words: communication; hazard; pictogram; safety; signs; standards; symbols; visual alerting; warnings

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EXECUTIVE SUMMARY

Written signs are commonly used in industrial sites to provide hazard warnings and safety information. The use of safety symbols and pictorials may increase the effectiveness of safety communication. Because such signs are language-free, they can be recognized more rapidly and accurately than written signs, even under some conditions of interference and distraction. The effectiveness of safety symbols critically depends upon the selection of symbolic images which are readily understandable to the intended audience.

A four-phase evaluation of a set of selected workplace symbols is described in the following pages. First, thirty-three messages (referents) important to workplace safety were selected, based upon industrial site visits, sign catalogue review, and safety standard examination. These messages were divided into five categories: hazards; protective gear; first aid and emergency equipment; prohibited actions; and egress.

Secondly, two to 40 symbolic images were collected for each of the 33 referents. These images were rank-ordered according to their appropriateness for a given referent by thirty participants drawn from the graphics and safety communities. Three to five images for each referent (for a total of 87 images) were selected from the preference rankings for further experimentation, except for five messages for which nationally standardized images already exist. These include laser, biohazard, radiation, fire extinguisher, and standpipe. The final set of images for each referent represented a range of abstraction, complexity, activity, and use of the human figure. (The authors hypothesized that less abstract figures engaging in activity might be better understood.)

The final two phases (conducted as a field study) consisted of both an understandability determination and a preference ranking. In the first phase, 222 employees from industrial plants in three disparate geographical locations provided a short definition of the meaning of each image. The images were shown one at a time in a random order. Subjects saw only one symbolic image for each referent. In the second phase, all the images for each referent were presented along with its intended meaning, and participants selected the image that best conveyed the intended meaning to them, and indicated reasons for the preference. Similar data were obtained from a pilot group of 78 participants who were not familiar with workplace hazards, so that the effects of workplace experience on symbol understandability could be examined.

Symbol understandability, in terms of percentage of correct responses and confusions, varied widely for the thirty-three referents and for the images tested for each referent. Despite standardized use for a number of years, the radiation, biohazard, and laser symbols were frequently misidentified. Symbols for protective gear, first aid and emergency equipment were generally correctly identified. The different symbolic images selected for the various hazards showed the greatest range in understandability, with versions for entanglement, electricity, corrosion, and overhead hazard being quite different. Referent messages for which all symbolic versions recieved less than 85 percent correct responses included radiation, laser, biohazard, general warning, poison, combustible, eyewash, exit, no entrance and no exit. The first four referents did

particularly poorly for both informed and naive participants. The preference data generally supported the understandability data, with the most correctly identified image usually being the most preferred image. Participants also provided insightful comments about the reasons for their choices, including ideas about the visibility, pictorial nature, and effectiveness of the images proposed for each referent.

The conclusions reached in this report are necessarily tentative, based upon a small set of industrial employees. They do, however, provide some indication of the image content which could communicate particular safety messages successfully. Further research into the effectiveness of workplace safety symbols and hazard pictorials is now in progress.

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SI CONVERSION

The units and conversion factors given in this table are in agreement with the International System of Units or SI system (Systeme International d'Unites). Because the United States is a signatory to the 11th General Conference on Weights and Measures which defined and gave official status to the SI system, the following conversion factors are given.

Length

1 inch = 0.0254* meter
1 foot = 0.3048* meter

Area

1 square inch = $6.4516^{*} \times 10^{-4}$ meter^2
1 square foot = 0.0929 meter^2

Volume

1 cubic foot (ft^3) = 0.0283 meter^3

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* Exactly

1. INTRODUCTION

1.1 NEED FOR SYMBOL USE

Written signs have traditionally provided information to guide, protect, and inform people in buildings in the United States. Written signs are commonly used in industrial settings, where they play an important role in worker safety. The importance of worker safety is underscored by the statistics that more than 5.6 million people were injured, and at least 4500 were killed, in workplace accidents in the United States in 1978 (Bureau of Labor Statistics, 1979). Injury is most likely during the first month on the job, and the "incidence of injury or illness decreases with length of service in all age groups" (National Safety Council, 1979, p. 26). Consequently, signs may be particularly important in alerting the new worker who is less familiar with existing hazards and precautions. Despite the prevalence of written signs, however, these may not be the best way of conveying necessary information. As a result, there has been a tremendous growth in the use of pictograms or symbols. With these, the information is conveyed pictorially, often without word labels.

The modern use of pictograms began with the development of standardized traffic symbols in Europe in the early part of this century. Currently, there is increasing use of symbols within the United States for transportation systems, hazard warnings, fire safety, and public information. For example, the Department of Transportation (DoT) successfully sponsored the implementation of standard symbols for motorists, and has proposed other symbols for public information in transportation facilities. Increased concern for worker safety and consumer protection has sparked interest in the United States in the use of symbols as a viable means of communicating safety information.

Pictorial signs or symbols, when chosen appropriately, have been demonstrated to be more effective than words. Thus, symbols can be recognized more rapidly (Janda & Volk, 1934) and more accurately (Walker, Nicolay & Stearns, 1965) even under conditions of interference or distraction (King, 1975; Ells & Dewar, 1979). Furthermore, they often occupy less space (Forbes, Gervais & Allen, 1963) and may be more effective in altering behavior (Forbes et al., 1963). In addition, they provide information without the use of a specific written language.

The reasons for developing symbols for use in industrial settings lie in the numerous advantages of symbols. The primary advantage is that pictures communicate information without the use of written language (Mead & Modley, 1968; Modley 1966). Symbols have been used in Europe because the prevalence of international travel and trade created the need to overcome language barriers (Kolers, 1969). Even within the U.S., there are large numbers of people who do not read or speak English well. Because there are no established criteria for functional literacy, estimates of illiteracy vary widely from about two million to about 64 million adult Americans (Kirsch & Guthrie, 1977-1978; Washington Post, 1979). Furthermore, Bureau of the Census data, collected in 1976, indicated that English was not the native language for about eight million people the U.S. Of these, about five million reported difficulty in speaking or understanding English. (There were no reported data on reading skills). For

those whose native language is not English or who are functionally illiterate, symbols could be the only visual warnings for preventing accidents and providing protection.

1.2 REQUIREMENTS FOR RESEARCH ON WORKPLACE SAFETY SYMBOLS

An overview of the research literature on symbols (presented in more detail in section 2.0), underlines some additional advantages of symbols. Among the major advantages are that pictograms can, in some cases, be perceived more rapidly (Janda & Volk, 1934), more accurately (Walker, Nicolay & Stearns, 1965), and at a greater distance (Smith & Weir, 1978) than words. Reaction time may be shorter to symbols (Smith & Weir, 1978), even under conditions of stress (Smillie, 1978). Symbol meanings can often be rapidly learned and accurately remembered (Walker, et al., 1965), with minimal confusion among alternatives (Green & Pew, 1978). Symbols may also be superior to words under conditions of interference either by distraction from another task (King & Tierney, 1970) or by visual interference or degradation (Ells & Dewar, 1979). These advantages of symbols over words may not be true under all conditions, however.

Most of this research has focused on highway signs, with some attention to applications such as automotive machinery and product labeling. Yet these experiments have, for the most part, ignored the use of symbols to convey safety messages within buildings. As a result, their effectiveness for this purpose has rarely been evaluated.

Although symbols can be more effective than written signs, their effectiveness depends heavily upon selecting symbols which are readily understandable. Simply drawing a picture is not sufficient. The picture must be evaluated in a systematic research program. Yet, this evaluative stage is rarely done, because symbols are typically developed and implemented in response to an individual, specific need. Although the creator of a symbol may understand its meaning perfectly, this message may not be communicated to anyone else. Collins and Pierman (1979) and Lerner and Collins (1980) noted that several fire-safety symbols developed by ISO TC 21 communicated a meaning which was the opposite of the intended message. A situation in which a symbol communicates an opposite meaning illustrates the most serious problem with the use of symbols. As a result, before symbols are standardized, particularly for safety situations, their effectiveness in communicating the appropriate message must be evaluated.

Once a symbol has been developed to fill a specific set of needs and researched to determine its effectiveness, it should be standardized for a given application. A major problem currently is that anyone who feels the need for a symbol develops one, often without reference to existing symbol sets. Figure 2 shows an example of eight different conceptualizations for symbolizing hearing protection. Each of these basic forms may have several graphically distinct renditions in use. This illustrates how the same message may have several different graphic images. If the representation of each of these symbols is very different, the potential for serious confusion is great. Therefore, there is a need to develop consistent and ultimately standard sets of safety symbols for use in workplaces. Because the signs currently used in workplaces provide critical information for preventing accidents and for providing personal

protection, failure to develop and implement consistent, well recognized symbols is potentially dangerous.

The task of developing effective workplace symbols is threefold. First, a determination must be made of the kinds of situations which require symbols. Exactly what messages, or referents, need to be conveyed and for which hazards? Secondly, a set of candidate symbols must be selected for each referent, particularly where there have been numerous attempts to symbolize a given referent. Thirdly, the various proposed symbols must be evaluated to determine if they, in fact, communicate the desired meaning to the target audience. In this process, it is important to realize that because some situations are more difficult than others to symbolize, the process of developing effective symbols must be an evolutionary one.

In the following pages we will review the research literature; describe site visits and conclusions from visits to factories; review catalogues and correspondence with numerous sign manufacturers; develop a list of symbol referents for further investigation; review national and international standards for symbol use; present an experimental evaluation of symbolic images for 33 different safety messages; and discuss recommendations for the use of safety symbols in industrial settings.

2. OVERVIEW OF SYMBOL RESEARCH LITERATURE

2.1 BACKGROUND

Before symbols are implemented as part of a communication system, their effectiveness in conveying information and producing the desired behavior must be evaluated. For a symbol to elicit a behavioral response, a series of psychological processes must be completed. These include detection, discrimination, recognition, and understanding (or identification). (For a further discussion of perceptual information processing, see Schiff, 1980.) A symbol must be effective at each stage of this process if it is to be a reliable means of communication. Research on symbols has focused on various stages, asking such questions as: How detectable is the symbol? How discriminable is it from all other symbols? How recognizable is it when seen in a different context? How well does it communicate the desired meaning? How effectively does it alter behavior? In addition, some experimenters have assessed people's attitudes toward, and preferences for, specific symbols.

In the literature review that follows, it will become apparent that some stages of the communication process have received relatively little research attention. Furthermore, most symbol systems have not been studied systematically. For the most part, researchers have concentrated on detectability and understandability as the major research areas for symbols. Although the bulk of the research has concentrated upon highway symbols, this review will discuss the application of symbols in four areas: road and highway symbols; vehicle and machine symbols; public information and directional symbols; and product hazard symbols. Workplace safety symbols have received little research attention, although some relevant experimental results will be discussed at the end of this review.

2.2 HIGHWAY SYMBOL RESEARCH

The bulk of the highway symbol research has centered upon a comparison of the effectiveness of word and symbol signs, typically for response accuracy or reaction time. In several other instances, a set of symbols has been directly evaluated for its understandability. Finally, several investigators have assessed the effectiveness of highway symbols in terms of perceived meaningfulness, discriminability, or alteration of behavior.

2.2.1 Direct Comparison of Word and Symbol Signs

One of the first highway symbol experiments was conducted by Janda and Volk (1934) who assessed the speed of reaction to 20 signs and symbols. They also assessed the correctness of response by having subjects push a lever in the direction indicated by the various symbols and signs. Reaction time was shortest for the symbols and greatest for the words alone with a total difference of 200 msec. In addition, speed of response increased with repeated trials. The authors claimed consequently that word signs are a relatively poor way of conveying information to people.

In a later comparison of word and symbol signs, Walker, Nicolay, and Stearns (1965) compared both the accuracy of understanding and the ease of learning for

international highway symbols and U.S. highway (word) signs. The authors presented seven black and white signs and symbols for .06 sec tachistoscopically after five minutes of familiarization.

Subjects identified the nature of the sign or symbol in writing, after it was presented briefly. This procedure was repeated using colored stimuli for a new set of subjects. Finally, subjects defined the meaning of the symbols in a subsequent test of retention. In all cases, the authors found that the international symbols were identified significantly more accurately than the word signs regardless of color and delay before re-testing. They attributed the better performance of symbols to their perceptual simplicity and visual integration.

A number of researchers have used a measure termed "glance legibility" to assess the effectiveness of word and symbol signs. As defined by King (1971, 1975), glance legibility is the percentage of correct matches between a symbol (or word) stimulus and an answer chosen from an array of symbols or words. The tachistoscopic presentation of the test stimulus is limited to brief exposures. Both the time to make the match and the accuraccy of the match are recorded. Glance legibility essentially measures the recognizability of a symbol.

King (1971) used the glance legibility procedure to compare the meaningfulness of two series of 10 symbols each with one series of 10 road signs for 208 subjects. First, King had subjects give a definition for each symbol. Then, King presented each symbol briefly (.05 sec and .3 sec) so that subjects could match it against an answer array of nine symbols. King found that there were significant differences in the accuracy of response for the two series of symbols; the series which contained prohibitory symbols proved to be especially difficult to define. When glance legibility was assessed, the percentage of correct matches decreased for word signs as presentation time decreased, but not for symbol signs. There were no differences in correct response between the two series of symbols, however. Finally, 65 percent of King's subjects claimed that the symbol signs were easier to match than the word signs. Thus, although the word signs may have been initially more meaningful, under short presentation times, symbols were more recognizable and more accurately matched.

In a subsequent experiment, King (1975) used the glance legibility approach to study the effects of delayed response with and without interference during the delay, upon the accuracy of symbol recognition. Under actual driving conditions, there is typically a time interval between observing a highway sign and acting upon it. In addition, the driver usually performs some other driving-related task during this time interval. Consequently, King (1975) repeated his earlier experimental procedure but delayed the subject's response for intervals of 5 and 10 seconds and added an interference task during another 10 second interval. The symbols, signs, and presentation durations used in King (1971) were repeated. For the short (.05 sec) viewing conditions, the percentage of errors increased for both the 10 sec delay and interference conditions. In addition, even more errors occurred for the word signs under interference conditions. King suggested that his results indicate that symbols retain their superiority under difficult viewing conditions.

Plummer, Minarch, and King (1974) also used the glance legibility task to compare reaction time and response accuracy for 10 highway word and symbol signs. They presented a single word or symbol for 200 msec. Subjects selected an answer from an array containing either three words or three symbols which was presented for 6 sec. Each comparison was repeated 3 times for a total of 60 observations for each subject. In addition 10 subjects received special training on highway signs. The authors found that the reaction time, or time to select an answer from the answer array and depress the correct button, was slower for symbol signs than for word signs. The response to symbols was significantly more accurate, however. Prior training decreased reaction time but did not affect accuracy. Finally, individual symbols varied both in response time and recognition accuracy.

Dewar (1976) used the glance legibility procedure to determine the effects of a prohibitory slash upon symbol recognition. Fifteen symbols were studied under four different ways of symbolizing prohibition: slash superimposed on the symbol, symbol superimposed on the slash, partial slash, and circular red surround. Both normal and degraded viewing conditions were studied. In each, legibility was greatest for symbols with a red surround and least for symbols with the symbol superimposed upon the prohibitory slash. Nevertheless, because the use of a red circle to indicate prohibition would not be effective for most color defective people, Dewar recommended the use of a partial slash.

It is important to remember that Dewar's (1976) experiment was a recognition experiment in which he did not assess the meaningfulness of the various prohibitory conditions or compare different permissive and prohibitory versions of the same symbols. Nevertheless, his results do indicate that the slash can impair the detectability of the symbol underneath. As a result, it is particularly important to ensure that the underlying symbol is not overly complex. Resolving the issue of complexity is, in itself, a difficult question which deserves further research.

In a later experiment Dewar and Ells (1977) compared accuracy scores from a glance legibility experiment with the meaningfulness of the same symbols using the semantic differential. The semantic differential measures the meaningfulness of a word or idea by having subjects rate the sign on a set of scales made up of bipolar adjective pairs. In a test of 20 traffic symbols, Dewar and Ells found that meaningfulness as defined by the semantic differential was highly correlated with the accuracy of a subject's definition of a symbol. In a second experiment, Dewar and Ells were able to correlate glance legibility with semantic meaningfulness only for word signs, not for symbol signs. The authors did not explain this lack of correlation but suggested that both semantic differential and glance legibility measures are needed to provide a complete picture of a symbol's meaningfulness and recognizability.

In a reaction time experiment which did not use the glance legibility procedure, Dewar, Ells and Mundy (1976) compared the effectiveness of word and symbol signs for three tasks of increasing complexity. In the first task, subjects were shown slides of 26 signs (half verbal and half symbolic) and asked to classify 20 of these as either regulatory or warning. Reaction time was measured from the onset of the slide to the onset of the verbal (classification) response.

In this study, the experimenter first read a traffic sign message aloud. The subject then viewed a slide of a traffic sign and responded "yes" or "no" if the visual sign and the verbal message were the same. The time to initiate the verbal response was measured. Stimuli were viewed under both normal and degraded conditions. In this experiment, reaction time was always shortest for symbolic messages. In addition, response time increased more for verbal signs than for symbolic signs under degraded viewing conditions. Thus, the change in response method from the Dewar and EUS (1977) procedure) enabled the more rapid detectability of symbolic messages to be measured under all viewing conditions.

These experiments indicate clearly that symbolic signs can be more effective than verbal signs, if the response measures and viewing conditions are chosen appropriately. Because the use of a strictly verbal labeling response would appear to bias the reaction time data toward word signs, Ells and Dewar's (1979) experiment offers an interesting experimental approach alternative. Nevertheless, the use of reaction time as a measure provides an index of some of the demands of actual driving, where the speed of responding to a sign's message can be critical.

2.2.2 Assessment of Meaningfulness

In a different experimental approach, highway symbols have also been directly evaluated in terms of their understandability. Meaningfulness has typically been assessed to determine if a set of symbols is accurately understood. Speed of response has not been a critical variable in these experiments.

In one of the first assessments of highwway symbol meaningfulness, Brainard, Campbell, and Elkin (1961) evaluated the effectiveness of 30 European symbol signs. Meaning was assessed first by having subjects either give a definition for each symbol or select the correct answer from an array. Following this, subjects received a brief training period after which they again provided definitions for each of the symbols. Next subjects sketched their idea of an appropriate symbol for each of 16 definitions. Finally, a new set of subjects gave definitions for each of the new symbol signs.

Brianard et al. found a high correlation between the answers for both the definition and selection answers, although there were fewer correct answers for the definitions (54 percent rather than 74 percent). Training improved the percentage of correct answers to nearly 100 percent for both response modes. The analysis of the drawings revealed common stereotypes for at least nine of the 16 definitions and common elements for the majority of the symbols. Testing of symbols based upon these stereotypes revealed that the percentage of initially correct answers to them was greater than for the European symbol signs in all instances. The signs with the lowest scores tended to be more abstract or to use a prohibitory slash. Brainard et al. found that the meaning of prohibitory signs was frequently reversed, although brief training on all symbols improved accuracy to near 100 percent. It should be remembered that this experiment was published in 1961, before the current extensive use of prohibitory circle-slash signs by the Department of Transportation, so that more recent studies might have not unearthed a similar problem.

Griffith and Actkinson (1977, 1978) also evaluated the understandability of highway symbols. They determined the effectiveness of 128 road symbols used in Germany. Using U.S. Army personnel, they found that at least 10 of the 128 signs were misunderstood by more than 50 percent of the subjects, and that the overall percentage of errors upon first exposure was quite high. In addtion, they also found that memory cues and verbal elaboration were not significantly effective as training procedures, although each reduced errors somewhat. As a result, these authors questioned the ready interpretability of many highway symbols and claimed that their subjects had trouble with more abstract and less directly representational symbols.

Although Griffith and Actkinson did not comment upon it, the very large number of symbols studied (128) may have caused problems--particularly since some contradict U.S. practice. In some instances, for example, a red circle alone was used to indicate prohibition, with the slash used to lift the restriction, so that the meaning became in essence a double negative. By contrast in the U.S., a red circle is used with the slash to indicate prohibition. As a result, it is not surprising that Griffith and Actkinson's subjects had problems with these symbols.

2.2.3 Behavioral Observations of Symbol Effectiveness

The meaningfulness of symbols has also been assessed directly by determining their effectiveness in altering behavior. Forbes, Gervais, and Allen (1963), for example, developed a lane-control symbol in a set of laboratory experiments, and then tested its effectiveness on the highway. In the initial tests, the authors determined that a red "X" appeared to be most effective in controlling traffic lane use. This symbol was then tested under actual highway conditions, in which a lane was closed off by a lightweight barrier. Presence of the barrier was indicated by the red "X". Thus, Forbes et al. found a symbol which tested well under both laboratory and actual highway conditions.

In a similar experiment, Dewar and Swanson (1972) evaluated a set of symbols in a laboratory setting and then tested some of these symbols under actual driving conditions. Initially, they compared twenty-three word and symbol signs by having subjects define each one when presented under short viewing conditions (.04 sec). The signs were presented first by themselves, and then in a picture of a road intersection. For the most part, the symbols were recognized more accurately than the words, although some combinations of symbols and words reduced understandability compared with either alone. In a subsequent highway experiment, the relative effectiveness of positive (prescriptive) and negative (proscriptive) symbols for "no left turn" was determined by counting the number of cars making illegal left turns at an intersection. The positive symbol appeared to be more effective in altering behavior in the desired direction than the prohibition symbol.

2.2.4 Visibility of Highway Symbols

In the final experiment to be reported on highway symbols, the discriminability of a symbol was determined for different visibilities. Smith and Weir (1978) evaluated the effectiveness of eight different directional symbols under

conditions of blur and low contrast. "Blur" simulated the effects of different visual acuities upon visibility, particularly for nighttime conditions, while "contrast" simulated the effects of glare, as from bright sunshine. Eight levels of both blur and contrast were studied. In both experiments, subjects judged the direction in which the symbols pointed. Smith and Weir also determined subjective assessments of each of the 8 directional symbols. In this phase, subjects arranged photographs of the 8 symbols according to their suitability as a directional indicator. Smith and Weir found that although two symbols tested particularly well in terms of visibility criteria, one of these symbols was ranked as the least acceptable symbol. As a result, they suggested that criteria for symbol effectiveness must consider not only detectability and discriminability but also subjective response. The most effective symbol should perform well under all criteria.

2.3 AUTOMOTIVE AND MACHINERY SYMBOLS

Pictograms and symbols are also used to mark controls and to provide operating information in cars, trucks, and machinery. The impetus for this application derives from the international sale of machinery and equipment and the consequent need to convey equipment operating information accurately without the use of written language. Because symbols can be smaller than a comparable word phrase, they are preferred to lengthy written instructions for providing operating information.

Unlike highway symbol research, research into automotive-machinery symbols has focused on evaluating the effectiveness of one or more sets of symbols for a particular referent. Rarely have researchers compared symbols with words or evaluated reaction time. Rather, the focus has been upon determining the meaningfulness of a set of symbols for a particular audience.

Cahill (1975, 1976) evaluated the interpretability of some of the symbols proposed by Dreyfuss (1966) for use on farm vehicles and industrial machinery. She studied the effects of both context and previous experience upon the understandability of ten selected symbols for 30 male subjects. Context was provided by using a drawing of the interior of a cab for a piece of heavy equipment so that subjects could locate the appropriate place for each symbol, and perhaps derive some meaning from this "context". Half the subjects received context; half did not. All subjects viewed slides of the symbols and provided definitions for each. Subjects were considered "experienced" if they had operated, designed, or serviced heavy industrial or farm equipment.

Analysis of the results indicated that context and previous experience facilitated accurate recognition of the symbols, although there was wide variability in the understandability of individual symbols. Furthermore, although context improved performance, it did not alter the relative ranking of the understandable symbols. Cahill (1976) noted that the understandability of the symbols appeared to be influenced by the kind of graphic representation used. For example, symbols such as "fuel," "horn," and "turn signal" were understood by most subjects. Cahill commented that these symbols are fairly direct pictorial representations of commonly encountered objects. Other symbols such as "engage" and "choke" were understood by very few subjects; neither received

a correct response from the "no context" group. Cahill (1976) claimed that, because these symbols are conceptual rather than pictographic representations, they are not all familiar even to technologically sophisticated users. In these instances, although experience and context can provide useful cues, symbol design is critical in determining the understandability of a particular symbol.

In a study of automotive control symbols, symbol design was also found to be a critical variable. Wiegand and Glumm (1979) evaluated the effectiveness of a single set of symbols proposed by ISO by having 125 U.S. subjects match pictures of 25 symbols to a list of 35 definitions. The percentage of correct identification was above 80 percent for 20 of the 25 symbols. Yet, two of the symbols, "choke" and "master lighting switch" performed poorly enough to warrant redesign. Wiegand and Glumm suggested that knowledge of the understandability of a set of symbols can be used to indicate where additional design or education is needed.

One of the best ways of selecting a set of symbols for standardization is to test several different graphic representations for each idea (referent). Thus, Heard (1974) evaluated the effectiveness of three different symbols for each of 24 referents for a very large number (2593) of licensed drivers in four countries. She studied three age groups as well: 16-25, 26-55, and over 55.

A total of 54 symbols were studied--three variations of each of 15 ISO symbols and one variation of 9 other symbols. These symbols were tested in the appropriate location in an actual automobile or an automotive mock-up. As subjects were read a driving scenario which involved each of 24 symbols, they touched each control at the appropriate place, using the symbol for identification. The time to find and touch the correct symbol was measured to the nearest 0.5 sec. Accuracy of response was also recorded.

Heard was able to select one symbol for each of twelve referents based upon significant experimental differences between the symbols in the three proposed sets. For recommendation, a symbol had to be understood correctly by more than 75 percent of the subjects and to be confused with other symbols no more than 5 percent of the time. Based upon these criteria, Heard (1974) recommended a set of symbols which performed significantly better than all other symbols in an actual vehicle under simulated driving situations.

Green and Pew (1978) also examined the effectiveness of 19 pictographic symbols used in automotive displays. They employed fifty subjects in a series of five tasks. First, they determined the subjects' familiarity with the symbol, by having them circle those that they were "reasonably sure" that they had seen before. Secondly, in a determination of "association norm" for each symbol, subjects were read driving scenarios similar to those used by Heard (1974) and asked to indicate which of several symbols was appropriate for each scenario. In the third task, subjects made estimations of the magnitude of the "communicativeness" of each symbol, (or how well it conveyed the desired meaning). In the fourth task, subjects were given training until they could associate each label correctly with the appropriate symbol. Finally, reaction time was assessed by recording the amount of time until the subject could respond "same" or "different" to a picture of the symbol and a label read by the experimenter.

Green and Pew found that education (technical vs. non-technical), road experience, and specific vehicle experience all affected a subject's symbol knowledge. In addition, analysis of task 1, familiarity, indicated that most symbols were unfamiliar; the mean number of familiar symbols was 2.6 out of a possible 19. The second task indicated that only 6 out of 19 symbols tested met Heard's acceptance criteria of minimum 75 percent recognition and maximum 5 percent confusion. In fact, many of the symbols which were confused with each other were also rated as being very poor for communication. Nevertheless, subjects were able to learn the symbol label pairs of the fourth task relatively rapidly (usually in 3 trials). Results for the fifth task, reaction time, indicated both a pronounced learning effect and variation in a subject's ability to do the task rapidly.

When Green and Pew examined correlations between tasks, they found that neither familiarity nor associative strength was strongly correlated with reaction time measures. Rated communicativeness, however, was highly correlated with associative strength and reaction time. Hence, this measure could conceivably be used as an effective measure of the utility of a symbol. The authors also noted that although sex and technical ability affected the initial recognition of a symbol, these did not appear to affect performance on the other tasks. Furthermore, although reaction time decrease with learning, it was affected by the discriminability of an individual symbol. Finally, the authors concluded that it is important to interview subjects to understand why specific symbols are mistaken and confused. The numerous confusions and mistakes reported by Green and Pew underline the need to research the understandability of specific symbols.

Because previous research had shown variability in the understandability of symbols, Green (1979) explored the development of better symbols for automotive controls and displays. First, Green had subjects draw symbols for each of seven referents. Then another group rated the meaningfulness of the six or seven most frequently drawn symbols for each referent.

In the first phase, 43 subjects drew pictures of seven referents--heater, air conditioner, fresh air vent, radio volume, radio tuning, tire pressure, and lamp failure. Three judges then scored these ratings by giving them labels such as "fire" or snowflake" or some similar term. The drawings were then grouped by label and the most frequently suggested drawings were used a stimuli for the second phase. In the second phase, 62 subjects gave estimates of the informativeness of the newly drawn symbols. Subjects were given sheets upon which the referent (label) appeared in the center surrounded by four to ten candidate symbols. Subjects made magnitude estimations of the informativeness of each suggested symbol for the various referents. Analysis of the data indicated that subjects were able to agree upon at least one symbol for each referent. These symbols did not always agree with those in common use, however. Green (1979) concluded that having people draw symbols for proposed referents (the "production method") should be the first step in data collection for symbol research. Magnitude estimation should then be used to select the "best" of these symbols for a given referent for further study.

In a study of symbol discriminability, Green and Davis (1976) explored the effects of variation in the orientation of automotive symbol controls. Previous research, such as Heard (1974), evaluated the recognizability of automotive symbols placed in an upright position only. Yet symbols placed upon controls are often rotated away from upright, and consequently may not be rapidly or accurately identified.

Green and Davis presented ten subjects with three different symbols which varied in orientation. Subjects were given a page with numerous pairs of symbols, one of which varied in orientation. Half of the varied symbols were also reversed (mirror image). Subjects judged whether the symbol pairs were the same (S) or different (D) (mirror image reversed). Analysis of the results indicated that increasing the rotation of the symbol away from upright significantly affected response time for deciding if both members of the pair were the same. Green and Davis commented that this delayed reaction could be hazardous in an actual driving situation. As a result, because a driver could have difficulty in responding appropriately in an emergency, control symbols should always be mounted in an upright position. The problem of rotated symbols is greatest for controls which themselves can be moved away from a "normal" position.

2.4 PUBLIC INFORMATION SYMBOLS

The third application of symbols to be discussed is that of public information symbols. These are symbols which provide primarily directional information to the general public. Intended to be understood by a wide variety of people who do not speak a common language, they are frequently used in transportation facilities.

Research in this area has typically focused upon the meaningfulness, or understandability, of a set of symbols. For example, Easterby and Zwaga (1976) assessed the meaningfulness of various symbols for six informational referents under the sponsorship of the ISO. In a three stage experiment, they determined the "best" symbol for the following referents: drinking water, information, stairs, taxi, toilets, and waiting room. First a small sample of subjects from the U.K. and the Netherlands ranked a large number of symbols in terms of their "appropriateness" for a given referent. Three symbols were chosen from these rankings for each referent for further research. In the second phase, subjects from six countries gave meanings for each of the three symbols sets.

Easterby and Zwaga found that subjects were able to provide a more-or-less accurate definition for some symbols. Other symbols, however, received few correct definitions and a high percentage of "don't know" answers. Symbols that were readily understood were highly pictorial rather than abstract.

In the third phase, groups of subjects from six countries matched each of six referents against a group of 24 symbols. Different groups received one of three versions of the symbols being tested for the six referents. (Eighteen of the symbols merely provided choice alternatives). Each subject matched only one version of a symbol for each referent. Easterby and Zwaga found that the matching test allowed them to select a "good" symbol from a set of symbols, but

was limited by the quality of the symbol set. Thus, the matching test would not allow subects to indicate that none of the symbols was particularly effective. As a result, the authors recommended that a matching test be done after recognition testing has indicated the most "meaningful" symbols.

Both the matching and recognition test data provided valuable insights into the confusion between symbols, as well as the kinds of alternative answers given by subjects. These data were instrumental in selecting the set of public information symbols currently recommended by ISO.

The other major evaluation of the effectiveness of public information symbols was commissioned by the U.S. Department of Transportation (DoT). First, DoT sponsored the design of a set of 34 public information signs by the American Institute of Graphic Artists (AIGA). After compiling a list of existing symbols for each referent, the AIGA (1974) then designed what they considered to be the best symbol for a given referent based upon this compiliation.

The list of symbols developed by the AIGA was evaluated by the Franklin Research Institute. In an interim report, Freedman, Berkowitz, and Gallagher (1976) used a variety of both paper-and-pencil and performance tests to assess the symbols. These tests were designed to assess the recognizability of the symbols, elicit confusions, and provide an indication of the relative difficulty of the symbols. While the initial tests were designed as input to a subsequent, large-scale testing phase, they did indicate that the symbols varied widely in initial recognizability. For example, only eleven of the 34 symbols were understood by all subjects.

Following completion of the paper-and-pencil tests of appropriateness, subjects completed a "walking rally." In this test, subjects followed the symbols to various locations within a building. Time to arrival and correctness of the destination were monitored. Freedman and Berkowitz (1977) also administered matching multiple choice tests at an airport and a subway station, and are in the process of a large-scale test of the 34 symbols at a variety of transportation facilities.

Preliminary comparison of the paper and pencil data with the field data indicated few differences in the subjects' responses. Because about 9 symbols were missed by a large number of subjects, the authors proposed several criteria for effectiveness. They suggested that symbols which are recognized by 60 percent or fewer people are clearly unacceptable, while those recognized by more than 80 percent are acceptable. Finally those recognized by 60-85 percent need some improvement.

These two research projects have assessed the meaningfulness of public information symbols with large groups of people--people who would likely use these symbols. Unlike the highway symbol research, no assessment of the speed of detection was made, nor were the symbol signs directly compared with word signs. As with automotive/machinery applications, meaningfulness or understandability appears to be the most useful characteristic by which to evaluate public information symbols, and certainly is the most frequently used by researchers.

2.5 PRODUCT LABELING SYMBOLS

Another emerging application of symbols is that of product labeling. While the Canadians, the British, and the Common Market (EEC) have all proposed or adopted standards for warning consumers of potential hazards, there is little if any research on the effectiveness of these symbols. In addition, several controversial product labeling symbols have been produced in the U.S. These include "Mr. Yuk," produced by the Pittsburgh Poison Control Center, to replace the skull-and-crossbones to warn children of poisonous substances, and the lawnmower and CB antenna symbols developed by the Consumer Product Safety Commission (CPSC) to warn consumers of potential accidents. While these symbols have generated much discussion, only the effectiveness of Mr. Yuk has been researched. "Mr. Yuk" has been found to be understood by small children as indicating a hazardous ("yuky") substance, although its effectiveness for adults has not been reported.

One of the few extensive assessments of product labeling symbols was conducted in Great Britain by Easterby and Hakiel (1977a, 1977b, 1977c). In their first study, Easterby and Hakiel (1977 a, 1977b) had people design signs to convey fire, poison, and caustic hazard information. Subjects were provided with a selection of image forms and colors, background colors and shapes, enclosure shapes and colors, surround shapes and colors, and supporting field colors.

Analysis of the results indicated that red was the preferred color for fire signs while black was preferred for poison. Both red and black were equally liked for caustic. Easterby and Hakiel (1977b) commented that these colors appear to be chosen to indicate the identity of the hazard, and, consequently, reinforce the function of the image. The stereotypes generated in this series of studies were used to construct signs for a subsequent study of the understandability of product-warning signs.

In the final study, Easterby and Hakiel (1977c) evaluated product-labeling signs by first having students rank-order a set of symbols in terms of their effectiveness in conveying a given message. This procedure reduced the large number of symbols found in a compilation of existing symbols to 4 symbols for each of 3 hazards (fire, poison, and caustic). The ordering experiment revealed that subjects preferred symbols which describe the hazard (descriptive) to symbols which prohibited a hazardous action (proscriptive) or prescribed a course of action to avoid a hazard (prescriptive). Furthermore, when there were several versions of a somewhat similar image, subjects preferred the visually more complex image to a graphically simplified one. It is not clear, from the authors' description, whether a complex image is also more graphically representational.

The symbols selected from the pilot test were then studied in a nationwide survey of 4,000 respondents in the U.K. The survey consisted of a recognition test in which each subject provided meanings for each of 17 signs--5 test signs and 12 contextual signs that might be found on consumer goods or in public environments. The five test signs included the poison, caustic, and fire symbols. All 4,000 respondents judged the 12 context signs, while only 500 respondents judged each variant of each hazard sign.

Analysis of the results indicated that attributes of the sign (image, color coding, and shape coding) and characteristics of the respondents (age, sex, household composition, and experience with signs) all influenced the recognizability of the signs. They suggested that symbols which have been extensively simplified from a graphic standpoint do not perform as well as more complex images -- which one can infer, resemble the intended referent more closely.

Easterby and Hakiel (1977c) concluded, however, that the single factor which primarily affects recognition performance is image content. Other factors such as color and observer characteristics are important, but ultimately the understandability of the sign will depend on the symbolic image chosen.

2.6 SAFETY SYMBOLS

Although there do not appear to be any studies which have assessed the effectiveness of symbols for workplaces, two studies have examined aspects of safety signs. One (Collins & Pierman, 1979) evaluated the meaningfulness of fire safety symbols. The other (Laner & Sell, 1960) determined the effectiveness of safety posters. Although Laner and Sell did not assess symbol use, their work is of interest because it measured the effectiveness of safety messages directly in terms of changes in unsafe behaviors.

Collins and Pierman (1979) reported an experiment in which they determined the understandability of 22 fire safety symbols proposed by ISO. They asked 143 subjects to provide a short definition for each symbol. Three judges rated the answers as "correct," "incorrect," or "no response." In addition a tally was kept of the number and kind of incorrect answers.

The authors found that some symbols such as "fire extinguisher," "no smoking" and the conventional U.S. "exit" sign were understood by almost all the subjects tested. Yet other symbols such as "blind alley," "do not block" and "break glass" were understood by less than 20 percent of the subjects. In addition, several symbols were given a meaning opposite to that which was intended. Thus, the "no exit" or "blind alley" symbol was interpreted as "exit" or "safe area" by almost all subjects who gave a definition for this symbol. Altogether over 95 percent of the subjects either misidentified or did not respond to this particular symbol. Lerner and Collins (1980) confirmed the fidings of the earlier experiment in a comparison of response methods. Again, they determined that both "exit" and "no exit" appear to be very difficult to symbolize effectively.

Collins and Pierman (1979) commented that an instance in which a symbol is given a meaning opposite to that which is intended is potentially very dangerous. They recommended that before symbols are adopted, particularly those which communicate emergency information, their effectiveness must be evaluated. A safety symbol must be understandable before it can begin to alter behavior and prevent accidents.

Laner and Sell (1960) examined the effectiveness of safety messages in altering unsafe behavior. Although safety posters with various sorts of warning messages

have typically been used in an effort to stop unsafe acts, their effectiveness in actually modifying these behaviors has rarely been assessed. Effectiveness could be measured by studying accident rate reduction directly, except that the frequency of accidents is so low that the experiment would be inordinately long. Laner and Sell also rejected the idea of measuring poster effectiveness in terms of the extent to which a poster could be recognized, remembered, or liked because these measures do not assess actual behavior.

Consequently, Laner and Sell (1960) selected a behavioral measure which could involve an operation that was potentially dangerous, frequently carried out, and readily measureable--namely, the hooking back of chain slings onto a crane hook when not in use. Seven steelworks participated in the experiment in which posters depicting safe steelworking practices were developed and displayed. First a baseline of behavior was established over five weeks without poster display. Then the posters were displayed. Behavior was measured for five weeks, followed by a lapse of 7 weeks without measurement, concluding with 2 additional weeks of measurement.

Laner and Sell found that the posters had a positive effect in the six test steelworks (substantial for four of these) but no effect in the seventh, or control steelwork. Furthermore, they noted that the behavior affected by the posters was at least maintained, if not improved, following the seven week period in which behavior was not measured. The authors suggested that these posters were effective either because they acted as perpetual reminders or because they established or reinforced working habits which were self-maintained. They also found that the increase in safe behavior was greatest in those shops with low ceilings where the unsafe practice constituted the greatest hazard to personnel. They concluded that posters may be more effective if the message they carry can be seen to be directly relevant to the situation. Such a conclusion may be extended to the use of safety symbols as well. In addition, the use of a behavioral measure--reduction of unsafe acts--is perhaps the ultimate measure of a sign or symbol's true effectiveness. Its use should be explored more for all applications of symbols.

3. DEVELOPMENT OF WORKPLACE SAFETY SYMBOL REFERENTS

3.1 OVERALL PROCEDURES

The preceding review of research on symbols indicated that researchers typically begin their evaluative process with an existing set of symbols for specific referents. These symbols were developed primarily by standards organizations, graphic designers, and manufacturers, so that the role of the researcher was confined to evaluating these specific images.

The case for evaluating symbols for workplace safety is a bit different, however, in that there is no single set of existing symbols. Rather, numerous symbols abound for some referents while few symbols exist for other referents. Further, the most important set of referents to symbolize has not been determined. Because there are no comprehensive standards in the U.S. for either referents or symbols for workplace safety signs, the first task in an assessment of symbols for workplaces is to determine the symbols that are currently used and the kinds of general situations which require hazard warnings. Secondly, a list of symbol referents which is broad enough to be applicable to most workplace situations must be developed. Finally, specific symbols for these referents must be selected and evaluated experimentally. These three steps have been followed in the present evaluation of industrial safety symbols.

In this section the various sources used to develop the initial listing of safety symbol referents are outlined. These sources included site visits, sign catalogues, and national and international standards. Each of these will be reviewed in turn. Finally a list of symbol referents based upon all of these sources is presented.

3.2 SITE VISITS

One source of information about current symbol use was observations of practice at six industrial sites. These industries included: the manufacture and assembly of heavy equipment engines; the manufacture of ceramic glass; the final assembly of aircraft; the chemical manufacture of vinyl acetate based resins; shipbuilding (manufacture, assembly, and repair); and oil refining. These sites not only provided a range of major industries, activities, and hazards, but also a spectrum of philosophies in workplace safety practices and sign use. Consequently, the plant visits provided invaluable background for this project. Details of the plant visits can be found in Lerner and Collins (1980).

Each industry has a unique set of major hazards associated with it activities, such as explosion, extreme heat, caustic chemicals, fire, etc. The most frequently reported injuries, however, often appeared unrelated to these major threats and were similar from plant to plant. These common injuries included slips (especially where oil, ice, or chemical substances could be found on the floor), hand and finger injuries, back injuries, eye injuries, and cuts. Safety officers often expressed the opinion that workers were cautious about major hazards and were more likely to be injured where work was routine and repetitious. Somewhat in contradiction, equipment maintenance workers appeared to

have especially high injury rates relative to other employees, and this was often attributed to the novel or unfamiliar tasks required of the maintenance staff. Safety signs seemed to be most frequently related to potential hazards, or protective gear rather than to common injuries.

In general, the six plants relied heavily upon word signs. Because employees were believed to be generally literate in English, there was little perceived requirement for pictographic signs. Nevertheless, the DoT hazard warning symbols for material transport were in widespread use, as were symbols for vehicle operating instructions and precautions. One plant, however, did deliberately use a large number of pictograms, primarily to remind personnel to wear safety equipment. This plant had a noticeable number of illiterate employees as well as foreign visitors. Symbols were also believed to be "eye-catching." In other factories, some specific hazards were symbolized pictographically. These included "no-smoking" at one site where there were foreign visitors, and "high noise area--ear protection required" in another plant. Other than these examples, however, the common practice was to use word signs--often quite lengthy word signs.

In some factories, because the use of color coded areas dominated safety communication, signs were relatively infrequent. In contrast to signs, this coding could be spatially precise, indicating the exact location and extent of the hazardous area. While the prevalance of yellow for hazard indication suggests the need to adopt a good pictogram indicating a general hazard, the general use of such a symbol as an alternative or supplement to simple color coding requires further consideration.

One question addressed during the site visits was the presentation of signs. In other words, where are they typically located, how are they illuminated, where are they located with respect to the hazards they represent, and what is the background against which they are presented? Although such details are expected to vary, there were highly idiosyncratic practices and extreme variability in sign presentation among the sites visited. Even the same message (such as eye protection required) was located in many different ways: signs were placed on stands in the aisles, or mounted on walls (sometimes well above eye level and out of the usual visual field), or above entrance ways, or on fixtures and equipment. Often, signs were presented in clusters, rather than singly. Lighting varied from signs poorly placed in shadow, to ones placed in bright illumination. Warnings were sometimes placed at entrances, sometimes located around the workspace, and other times mounted on or near the hazard. Sometimes warning signs were difficult to see due to clutter, poor maintenance, or blending into the background color. (In one case the predominant work material was colored yellow to yellow-green, making yellow warning signs obscure). As a result, no "typical" or "representative" contexts could be identified. What is a familiar context in one setting appears unusual in another plant, or even in another section of the same plant due to differences in hazards, layout, and sign usage.

Table 1 indicates the types of generic safety messages that occurred with high frequency across the various industries. The messages in the table are given in general form (e.g., restricted admittance), even though the wording of

Table 1: Common Generic Messages From Site Visits

Hazards;

- General
- Electrical
- Explosive
- Heat
- Caustic, acid
- Overhead
- Noise
- Slip/Trip/Watch Your Step
- Vehicles
- Radiation

Safety and Emergency Gear;

- Eye Protection Required
- Hard Hat Required
- Foot Protection Required
- Caustic-Handling Gear Required

- Breathing Gear
- First Aid
- Emergency Shower
- Eye Wash
- Fire Alarm
- Fire Extinguisher
- Fire Hose

Prohibitions;

- No Smoking
- No Flames, No Hot Work
- Do Not Touch, Keep Away From

Egress, Access;

- Walkway
- Exit, Emergency Exit
- No Exit
- Restricted Admittance
- Keep Area Clear
- Keep Door Open
- Keep Door Closed

individual signs may have varied (e.g., authorized personnel only, positively no admittance, restricted area, do not enter, etc.). While the messages in table 1 represent commonly occurring and important workplace signs, they should not be viewed as a complete list, given the limited number of plants visited.

3.3 SIGN CATALOGUES, PUBLICATIONS, AND MANUFACTURERS

In addition to the site visits, the following sources were reviewed for information on symbol availability: sign catalogues, sign manufacturers, individual company guidelines, and compilations of pictorial signs (Dreyfuss, 1972; Modley & Myers, 1976).

A list of the most frequent occurring kinds of symbols was compiled from this review and is given in table 2.

The review of catalogues and publications indicated many common symbols. These fell into categories such as protective gear, hazard warnings, prohibited actions and information about fire and safety instructions. In addition, at least one catalogue offered an extensive list of unusual symbols to fit most hazards. This report, however, concentrates upon the most frequently occurring symbols as being representative of current offerings from sign manufacturing catalogues.

To assess the demand for symbolic signs, twelve sign manufacturers were asked for information on sign use, including the most frequently purchased signs, the most frequently requested symbolic signs, and the perceived demand for symbolic signs. Although the responses differed greatly in terms of the detail provided, there seemed to be a feeling that demand for pictorial signs was increasing. One manufacturer of both written and symbolic signs observed a "very significant increase in the demand for pictorial signs," estimating an increase of "about 10 percent or better per year for the past five years." Another company still produced mainly written messages because it felt some messages could not be adequately conveyed symbolically. However, it added that this could change if there were changes in the standards to accommodate symbols. In general, the responses indicated industry interest in symbolic signs and concern over issues of standardization and effectiveness. Some sign manufacturers expressed a need for some form of agreement, but also indicated concern about proprietary rights for symbols developed by individual companies.

The manufacturers noted that many of the most widely requested pictographic signs were not safety related (e.g., men, women, handicap access, etc.). Perhaps the most frequently cited symbolic safety sign was "no smoking." While this pictogram varies somewhat, nearly all examples provided used the familiar image of a burning cigarette with a prohibitory slash through it. Other frequently occurring symbolic signs included those for protective gear (glasses, ear protectors, hard hats), flammable hazards, and fire equipment (extinguisher, hose). Although quantitative information on the use of these signs was not available, many additional examples of pictograms were provided during the review of sign catalogues.

Table 2. Symbols Typically Available From Sign Catalogues

Prohibition

No smoking
No open flame
Do not enter
Authorized personnel only
Keep out/no trespassing
Do not touch

Protection

Eye protection
Hard hat area
Hearing protection/noise area
Respirator required/self-contained breathing apparatus
Foot protection required
Hand protection required
Face protection required
Protective clothing required
Protective belt/harness required

Hazards

Radiation area
Electric shock/high voltage
Corrosive/caustic/acid
Flammable
Fork lift trucks/vehicles
Explosive
Poison
General hazard
Overhead hazard
Slippery surface/danger of falling
Laser
Falling objects/flying objects
Hot surface/danger of burns
Biological hazard
Crushing/entanglement

Fire

Fire extinguisher
Fire hose and reel
Fire alarm
In case of fire, use stairway
Do not use water to extinguish
Fire exit
Fire hydrant

Information

First aid
Safety shower
Eye wash
Smoking area/smoking permitted
Direction

Exit
Keep door closed
Stretcher
No exit/door blocked
Pedestrian crossing/crosswalk

There appears to be only partial correspondence between pictograms that appear to be most in demand from manufacturers and the written signs most frequently observed on plant visits. Although the pictograms -- for "no smoking," "protective gear," and "fire equipment" -- do in fact represent a subset of the most frequently encountered messages, it is that subset that can be most plainly and literally represented by a simple picture. Other frequent messages -- related to egress, restricted access, general hazard, doorways -- appear less in demand as pictographic signs. Correspondingly, the graphic representation of these messages varies much more from company to company. This suggests that developing an explicit consensus representation for such messages may be an important step in increasing demand for these symbols. [Such a consensus may arise through the ANSI Z535 subcommittee on safety symbols which has identified referents and symbols for further investigation.]

3.4 REVIEW OF SYMBOL STANDARDS

Another source that was reviewed is that of national and international standards for symbols. As noted earlier, there is no standard in the U.S. for workplace symbols, although ANSI has recently chartered the Z535.3 Subcommittee on Safety Symbols. The current OSHA standard does not deal directly with workplace safety symbols except for those for radiation and biohazard. DoT does use the international (U.N.) standard for symbols for the transport of hazardous materials. Because these symbols appear upon containers used in factories, they should be reviewed for consistency with workplace symbols. In addition, individual companies and government agencies have developed their own specific symbol standards (see the proposed Air Force Standard, DoT Transportation Symbols, Du Pont Symbols, and FMC symbols).

At the international level, the International Organization for Standardization (ISO) TC 80 has drafted a standard (DIS 3864.3) for worker safety symbols which is currently under consideration. The EEC directive (R/1455) provides a similar set of symbols and referents, as do many other national standards: Great Britain (BS 5378), Australia (AS-1319), Netherlands (NEW 3011), France (NF X08=003). See table 3 for a listing of common referents from these international standards. Symbol standards which tend to vary from the ISO norm are those from countries outside Europe. The Canadian Standard (CAN 3-Z321-77) provides a list of referents and suggested glyph (image) content for some 50 signs related to the occupational environment. Standards from Uruguay and Bolivia list only 6-8 symbols. Nevertheless a relatively limited set of common messages emerges from the review of existing standards.

3.5 SYMBOL REFERENTS RECOMMENDED FOR STUDY

After reviewing the wide range of symbol referents collected from sign catalogues, sign manufacturers, site visits and sign/symbol standards (both national and international), thirty-three referents were selected for further experimental study. This list, which is presented in table 4, is based primarily upon the frequency of occurrence of a particular referent in each of the sources.

Table 3. Symbol Referents Standardized by ISO and the EEC for European Application

ISO-DIS-3864.3

Safety Signs

Prohibition Signs

1) Smoking prohibition
2) Fire, open light, and smoking prohibited
3) Thoroughfare prohibited for pedestrians
4) Water as extinguishing agent prohibited

Mandatory Action Signs

5) General mandatory action - exclamation point
6) Eye protection must be worn
7) Respiratory protection must be worn
8) Head protection must be worn
9) Hearing protection must be worn
10) Hand protection must be worn
11) Foot protection must be worn

Warn Signs

12) General warning, caution, danger, risk
13) Caution - risk of fire
14) Caution - risk of explosion
15) Caution - risk of corrosion
16) Caution - toxic risk
17) Caution - risk of electric shock

Information Signs

18) First aid
19) General indication of direction

The EEC Directive (R/1455) adds the following referents:

1) Not drinking water
2) Caution - radioactive material
3) Beware - overhead load
4) Beware - industrial trucks
5) Emergency exit with symbols

Referents added by Australia, British, Dutch or Australian Standards

Caution - laser
Danger - biohazard
Slippery when wet
Danger compressed gas
Danger insufficient clearance
No admittance; no trespassing
Fire extinguisher
Eyewash
Safety shower
Safety stretcher

The referents are given in intentionally general form (e.g., "eye protection required"). At some point, further discrimination among referents may be required (e.g., "safety glasses," "safety glasses with side shields," "safety goggles"), depending upon the need to provide information about a specific hazard or action.

Table 4 is, of necessity, an incomplete list of important workplace safety messages. Additional referents should be studied as the need arises. The table contains messages that occur generally across various industries, rather than one of particular importance in some specific work area. Nevertheless, the selected items should be widely applicable. This list is a compilation of symbol referents, or the messages to be communicated, rather than a list of symbols.

Table 4. Selected List of Symbol Referents for Experimental Study

Access/Egress:	Restricted access, do not enter	
	Exit	
	No exit	
	Emergency	
	Use stairs in case of fire	
Prohibition:	No smoking	
	No open flame	
Protection:	Eye protection	Respiratory protection
	Ear protection	Hand protection
	Head protection	
	Foot protection	
Hazard:	Electricity	
	Fire	Slippery surface, watch your step
	Explosion	Entanglement
	General Warning	Fork lifts, vehicles
	Radiation	Laser
	Corrosion	Falling hazard
	Poison	
	Overhead	
	Biohazard	
Emergency;	Fire extinguisher	Fire hose
	Alarm call point	
	First aid	
	Safty shower	
	Eye wash	

4. RESEARCH ON WORKPLACE SYMBOLS

4.1 EFFECTIVE SYMBOLS: RESEARCH FOCUS

In sections 2 and 3 research methods and results were reviewed, and a list of siggested referents for workplace symbols was developed. In developing the list of symbol referents, it became clear that there was no single set of existing workplace symbols. The number of images for each referent varied from 2 to over 40. As a result, the assessment of effective symbols for workplace safety required selecting several plausible symbols for each referent, testing the understandability of each symbol, and using the most understandable symbol based upon experimental results. In the following sections a research project on the understandability of selected workplace safety symbols will be presented in detail.

4.1.1 Background

To be effective, a symbol must be understood; it must communicate the desired meaning to all those who encounter it. While understandability is a critically important criterion by which to evaluate a symbol, it is not the only one. A symbol must also be detectable at a given distance under specific light levels. A symbol must be discriminable, or distinguishable from other symbols within a particular set. A symbol must be recognizable, or be remembered and identified under different circumstances. A symbol must be graphically satisfactory and command attention. Finally, a symbol must alter behavior in the intended direction and facilitate conformance with the message. A fully effective symbol performs well in each of these areas. Understandability, however, is the key which unlocks the whole process of conveying a safety message.

As a result, the priority for the research on safety symbols presented in this paper is the determination of the understandability of several images selected for each referent. In this way, the most understandable image could be determined for a given referent. Determination of understandability is particularly critical for workplace safety symbols, where the consequences of failure to understand could lead to serious injury.

4.1.2 Symbol Selection Procedures

As noted earlier, evaluation of understandability should proceed in several stages. Where a large number of different images exists for a given referent, this number must be reduced if further research is to be practical. Use of a ranking procedure is a way of reducing a large set of symbols to a more manageable set for further study. In a ranking procedure, subjects order a set of images according to how well they believe that each image conveys the meaning of the referent. Easterby and Zwaga (1976) followed this procedure with small groups of subjects in two countries to select three sets of public information symbols. Similarly, Heard (1974) and Green (1979) had subjects rank order images for automotive displays and controls according to meaningfulness. Use of a rank-ordering procedure allows ordered selection of a limited set of symbols for more detailed research. It also suggests that the set of images tested should

be somewhat meaningful. As a result, ISO TC-145-SC1 recommends rank-ordering as the best procedure for reducing the size of a set of images.

When a large number of images does not exist, or where no existing image appears to be effective for a particular referent, use of the "production method" can be valuable. In this method, subjects are given a referent and asked to draw a symbol which conveys this meaning. Brainard et al. (1961) used the production method to generate highway sign images. Similarly, Green (1979) used this method to develop a set of images for automotive controls, and reported that a subsequent group of subjects was able to identify the "produced" set of images more accurately than a comparison set. In conjunction with a graphic artist, the production method is advantageous in producing a number of images which could be meaningful to a target group. The number can then be reduced through rank-ordering. Once a set of symbols has been ranked according to appropriateness for a set of referents, the highest ranked images must then be evaluated for their understandability to a new, larger group of subjects. Nevertheless, because of the large number of existing images for most workplace safety referents, the production method may be needed only at a later stage where no image has tested well for a particular referent. As a result, the production method was not employed in the present study to generate symbols for further analysis.

4.2 SPECIFIC IMAGE SELECTION

For the present study the ranking procedure was used to select the final set of images to be evaluated for each referent. About 30 representatives of the safety and graphic design communities rank ordered images for each referent in terms of their appropriateness. Participants rank ordered only the five best images for each graphic concept, although in some cases as many as 20-30 images were presented. They then rank ordered graphic concepts to determine which concept best conveyed the referent. Thus a two stage process of ranking symbolic images and graphic concepts was used to select one to five images which could convey each referent effectively.

The set of images selected by the rank order procedure for further experimental study represent a range of concepts which are presented in table 5. The images themselves are presented for each referent in the results section. Images that participants ranked as the best representation for each referent were generally included. These selections were modified by the following factors: need to include safety symbols suggested by the International Organization for Standardization (ISO) in the final testing and desire to select as graphically diverse a set of images as possible. In addition, only one image was selected for further testing for five referents because these images have already been widely standardized. These referents include laser, biohazard, radiation, fire extinguisher and standpipe. The final set of images selected represent the following sorts of general concepts: hazard (abstract or representational); prohibited actions; hazard consequences; protective gear by itself, on a human form or putting on gear; safety device by itself or in operation; and egress, typically showing a person and door or some abstract representation. The images selected also varied along the following dimensions: complexity - simplicity, abstraction - representation, presence - absence of human figure(s), and activity - inactivity. The use of color and surround shape also varied, and was determined

Table 5. Concepts and Images Selected for Experimental Research

Group 1 - Hazards

Referent	Concept	Image Content	Background Shape
Danger, flammable	Hazard	A - match in flames in triangle	Δ
	Hazard	B - flames in hazard triangle	Δ
	Hazard	C - flames alone	o
Danger, electrical hazard	Hazard	A - lightning in hazard triangle	Δ
	Hazard	B - stylized lightning in circle	o
	Hazard & consequences	C - hand receiving lightning	□
Danger, explosive hazard	Hazard	C - representative explosion in triangle	Δ
	Hazard	B - explosion alone - stylized	□
	Hazard	A - very stylized explosion	o
Danger, fork lift truck	Hazard	C - truck alone	Δ
	Hazard	A - truck w/driver	Δ
	Hazard	B - truck w/driver & bystander	o
Danger, corrosion hazard	Hazard & consequences	A - 2 consequences - material & hand	Δ
	Hazard & consequence	C - 1 consequence - hand	Δ
	Consequence	B - bandaged hand	o
Danger, poison	Consequence	A - bad taste	Δ
	Consequence	B - death-abstract	Δ
Danger, entanglement hazard	Hazard	A - gears alone	o
	Hazard	B - abstract gears	Δ
	Hazard & consequences	C - gears & hand	□
General warning	Abstract hazard	A - alert symbol--!	Δ
		B - don't symbol--X	Δ

Group 1 - Hazards

Referent	Concept	Image Content	Background Shape
Danger, overhead hazard	Abstract hazard	A - downward triangle	o
	Hazard	B - broken crane load	Δ
	Consequence	C - dented hard hat on head	Δ
Danger, laser	Abstract hazard	- bright light	Δ
Danger, radiation hazard	Abstract Hazard	3 triangles	Δ
Danger, biohazard	Abstract Hazard	Circles intertwined	
Danger, slip hazard	Hazard	A - boot, squiggle	Δ
	Hazard & consequence	B - 2 feet, horizontal, squiggle	□
	Consequence	C - man falling, surface	Δ
Danger, falling hazard	Hazard	A - boot in hole	o
	Consequence	B - figure falling	Δ
		C - figure falling, ledge	□

Group 2 - Protective Gear

Head protection required	Gear	C - hard hat alone	o
	Wearing gear	B - head wearing hard hat	o
	Putting on gear	A - putting on hard hat	o
Ear protection required	Gear	B - ear protection	o
	Wearing gear	C - head & protectors	o
	Putting on gear	A - putting on protectors	o
	Hazard	- ear, waves	

Group 2 - Protective Gear

Referent	Concept	Image Content	Background Shape
Eye protection required	Gear	C - goggles	⊏
	Gear	A - glasses	—
	Wearing gear	B - head & glasses	o
Foot protection required	Gear	B - 1 shoe	o
	Gear	A - 2 shoes	o
	Action	C - putting on shoes	o
Hand protection required	Gear	B - 1 glove	o
	Gear	C - 2 gloves	o
	Action	A - putting on gloves	o
Respiratory protection required	Gear	B - respirator alone	
	Wearing gear	C - head & mask - abstract	o
	Wearing gear	A - head & mask - representative	o
		- head & dust mask	o

Group 3 - First Aid/Emergency Equipment

First aid	Abstract: aid	A - cross	□
	Action: application of aid	B - bandage, hand, cross	□
Safety shower location	Device	A - abstract showerhead w/drops	□
	Device & use	C - drops w/torso	□□
	Use & operation	B - full figure pulling chain	□
Eyewash location	Action	B - stylized eye & drops	□
	Action	C - eye & spray	□
	Device & action	A - head, drops, basin	□

Group 3 - First Aid/Emergency Equipment

Referent	Concept	Image Content	Background Shape
Fire alarm call point	Device	A - bell	□
	Device	B - sounder & hammer	□
	Hazard, device	C - phone & flame	o
Fire extinguisher	Device	Extinguisher	□
			□
Standpipe	Device	Hose & Reel	

Group 4 - Prohibition

No smoking	Prohibited object	A - lit cigarette	o
	Prohibited object	B - lit cigarette simpler	o
No open flame	Prohibited object	C - match	o
	Prohibited object	B - match stylized	o
	Prohibited object	A - flame	o

Group 5 - Egress-Related

Emergency exit	Action	B - man, movement, door	□
	Hazard & action	A - man, movement, door, fire	o
	Hazard & movement	C - fire, figure, arrow	o
	Action	man running, door, arrow	-
Exit	Abstract	B - 2 semi-circles	-
	Abstract	A - (2) arrow in box	□
	Action - person involved	C - door, arrow, person	□

Group 5 - Egress-Related

Referent	Concept	Image Content	Background Shape
No exit	Prohibited action	B - man, door, slash	○
	Prohibited action	C - man, X on door	○
	Prohibited action	A - man, back to barred door	□
			-
No entry	Abstract	A - circle, bar	○
	Abstract: prohibition	B - man, large hand	○
	Prohibited action	C - man standing	○
	Prohibited action	- man walking	○
	Prohibited action	- fully clothed man walking	
Use stairs in fire, Do not use elevator	Action & hazard	A - flame, figure, stairs	□
	Action, hazard, prohibited action	B - flame, figure, stairs elevator, slash	○

by currently existing standards. Symbols were presented in the form indicated in the source from which they came.

The goal of the research reported herein is to compare the relative effectiveness of candidates images selected for each referent. Two studies were conducted: a pilot study to assess the intended procedures and a main study using these procedures. For the main study, participants were selected from industrial sites in four geographical locations. For the pilot study, participants were paid volunteers and students, all of whom were naive to the workplace. In addition to determining that participants could successfully follow the experimental procedures, the pilot study data also provided supplementary information on the effects of lack of industrial work experience upon safety symbol effectiveness. "Effectiveness" includes both understandability (or ability to provide a correct definition for a symbol) and preference (or selection of one of a set of symbols as most indicative of a previously given "meaning").

4.3 METHOD

4.3.1 Experimental Procedure

The experimental study (both pilot and main) consisted of two parts, one on symbol understandability (part 1) and one on symbol preference (part 2). In part 1, participants provided a definition of the meaning of 87 symbols proposed for workplace safety messages to provide an indication of the relative understandability of each of the proposed images. In part 2, observers selected the one of several candidate symbol images for each referent that best conveyed the safety message to them.

4.3.2 Pilot Experiment

Prior to initiating the main experiment with industrial participants, a pilot experiment was conducted. The procedure was similar to that of the main experiment with a few exceptions noted below. Because the pilot participants were successfully able to follow the experimental procedure, no changes were required for the main experiment. In addition to testing the experimental procedures, the pilot experiment served two additional functions. First, since it used as participants people who did not work in industrial settings, it provided data for comparison with findings from the workplace population. These findings may be particularly relevant for new workers, naive to the workplace, who have been shown to have much higher accident rate than other workers (National Safety Council, 1979). The second function provided by the pilot experiment was to decrease the size of the set of symbols tested. In five cases, four or five symbols for a given referent were initially tested; on the basis of the pilot results, only three were included in the main experiment.

The pilot experiment differed from the final experiment in three major ways: (a) Participants: The pilot experiment utilized 45 volunteers from the Gaithersburg, Maryland area and 33 industrial engineering students from the West Virginia University, for a total of 78 observers. In addition to not

working in an industrial setting, this group tended to be younger, and include more females, than the main experiment. As a result, participants from the pilot study will be termed "naive" in subsequent pages. (b) Symbols: As noted four more symbols were included in the pilot. In particular, additional images were studied for emergency exit, no entry, and exit. Preference data were also obtained for four images for hearing protection and for respiratory protection. (c) Procedure: In the main experiment, participants generally saw only one symbol for each referent message. However, in the pilot study, the majority of the participants saw all the symbol images for each referent; this is a more efficient means of data collection, but can have the drawback of inducing people to try to make distinctions between symbols when in fact no difference exists. To circumvent this problem, participants were instructed to respond to each symbol without regard for previously viewed symbols. In the preference portion of the pilot study, subjects were shown as many as five symbols, while in the main study a maximum of three images was presented.

In other respects, the pilot procedure was similar to that described below for the main experiment. The overall similarity of the procedures permits an initial comparison of the perception of safety symbols both by industrial workers and by those unfamiliar with the industrial workplace.

4.3.3 Industrial Site Participants

For the main study, four groups of industrial participants were selected from four disparate geographical areas. A total of 222 people participated, 201 males and 21 females. Group 1 consisted of 63 participants (62 M, 1 F) from the Phoenix, Arizona area. These individuals were drawn from a power company and a professional safety training class and represented the following types of occupations: electrician, electrical supervisor, electrical apprentice or helper, foreman, truck driver, cable splicer, welder, fire fighter, technician, and similar occupations. Of these 63 participants, 23 viewed all 87 symbols during part 1. Group 2 consisted of 67 participants from 10 industrial sites in the West Virginia, western Pennsylvania and western Maryland area. These participants, of whom 50 were male and 17 female, were drawn from a variety of industries including warehousing, candy production, floor covering manufacture, glass production, aluminum reduction, aircraft production, aircraft assembly, mobile crane, and manufacture of graphite electrodes. Group 3 consisted of 28 participants (27 male, one female) from a paper production plant near Washington, D.C. These participants were primarily first line supervisors. Group 4 consisted of 64 participants, 62 male and 2 female, from a home appliance manufacturer in Ohio and represented the following occupations: quality control inspectors, assemblers, repair, and maintenance. Industrial participants generally ranged in age from 20 to about 60 with an average age of around 35. At least two individuals were Spanish speaking.

4.3.4 Symbols Tested

In part 1, each participant provided a definition of the meaning of each image presented. In part 2 (preference), participants selected the image that best conveyed a particular safety message. Participants viewed only one image for

a particular message, except for 23 people in group I. Although these individuals saw all 87 images, they were instructed to define each image individually without reference to prior images. The authors hypothesized that there would be no difference in the percentage of correct definitions or of percentage of preference among the candidate symbolic images studied for each message.

A total of 87 images for the 33 referents was presented in part 1 (understandability) to the industrial participants. Only 79 images were presented in the preference portion, because for eight referents only one image had been assessed in part 1. The total set of 87 images included 16 safety symbols proposed by ISO TC 80 (1979) and four firesafety symbols proposed by ISO TC 21 (1978). All images studied are presented in figures 1-31.

4.3.5 Stimulus Material

Each symbol was initially silk screened onto a 30 cm x 30 cm (1' x 1') placard. Color slides were then photographed individually from each placard. Finally, symbols intended for use in the preference portion were photographed as a set for each referent. These symbols were labeled A, B, or C to facilitate choice by the observers. In general, slides or placards were used as convenient for the understandability portion of the experiment except for Group 4 where only individual slides were used. Slides of the symbol sets for each referent were used in part 2.

4.3.6 Procedure

An experimental session consisted of the following set of events: a) participants read and signed consent forms outlining the safety and Privacy Act information; b) instructions for the understandability portion were given, along with a practice example; c) participants provided definitions on the understandability of the images; d) instructions for the preference portion were given; e) participants selected preferred images; f) participants were debriefed. The entire session including one break required about 45 minutes.

Observers participated in groups of 4-25 in a variety of facilities. The symbols were presented in one of three random orders. Whenever possible participants from a given site were divided into three subgroupings. Each group received a different random order of symbols in part 1, and a different random order of referents in part 2 to control for possible order effects. In part 1, symbols were presented at a rather slow rate (about 30 s per symbol--or when everyone had finished responding). Participants were asked to "give a short definition of each workplace safety symbol that we present to you." They were instructed to "define what the image means," not merely "report what it represents." As an example they were shown the "knife and fork" symbol and told that it meant "restaurant" or "place to eat" not just knife and fork. In part 2, participants were told the meaning of each set of symbols and were asked to "indicate which one of the symbols you feel is best at communicating that meaning" and why. About 30 s to 60 s were allowed per referent. Complete instructions to the participants are presented in appendix A. After completion of part 2, observers were debriefed about the purpose of the experiment.

4.3.7 Scoring of Response Protocols

Answers for the participants in part 1 (Understandability) were scored as correct, partially correct, incorrect, or no answer. Three judges rated each answer. The judges initially discussed criteria for each scoring category and then independently scored all answers. Criteria included an assessment of the participant's knowledge of the hazard and possible precautions to take. Where the judges did not have initial agreement, they then resolved all discrepancies. In the few cases where discrepancies existed, discrepancies were resolved by further discussion among the judges. Where resolution was not achieved, the majority opinion was adopted. In some cases, discussed in detail in section 5, special response categories were also identified separately.

Performance of the participants in providing definitions are reported for four scoring categories: Wrong, (X), No Answer, (N), Correct, (C), and Lenient - a category comprised of fully and partially correct answers. Answers were considered partial if they: failed to indicate a prescribed action (e.g., "hard hat" rather than "wear a hard hat"); were too general, or too narrow, or failed to indicate the full meaning of the symbol ("don't discard lighted cigarettes" for "no smoking"). In addition, wrong answers were placed into two categories; wrong, where the answer was simply incorrect, and critical confusion, where the answer indicated a meaning opposite to that intended.

5. RESULTS AND DISCUSSION

5.1 GENERAL

The results of the experiment are summarized in figures 1-31. All figures present both understandability and preference data for the industrial participants, with similar data for the non-industrial participants included for comparison. The understandability portion of the figures indicates the percent of answers that were fully correct, (C) the percent that were either fully and partially correct (C+P) also termed leniently scored, the percent wrong (X), and the percent no answer (N). The results of chi-square tests (discussed below) indicate whether the distribution of answers, as correct, partially correct, or wrong, differed among the various symbols for each referent.

The preference portion of the figure indicates the percent of participants indicating a preference for each of the candidate symbols for a given referent. The results of statistical tests (see below) indicate whether there is any statistically significant difference in the number of participants preferring each alternative. The percentages of participants preferring each alternative symbol for a given referent generally do not sum to one hundred percent. This is because some participants indicated no preference, or did not put down any answer, despite the forced-choice instructions. Although generally small, the percent of participants not indicating a preference exceeded 5 percent in six cases (all 5-10 percent, except for General Warning where it exceeded 30 percent).

To evaluate the understandability data for the industrial participants for all symbols for a referent, chi-square contingency tests of the differences in response distribution for the several symbols for a given referent were used to compare the distribution of answers across the categories "correct", "lenient" (C+P), or "not correct" (wrong answer or no answer). In some cases, where expected cell frequencies were small (less than five), partially correct and not correct categories were combined; these cases are identifiable by the reduced number of degrees of freedom, indicated in the figures. To evaluate the preference for each alternative symbol, chi-square tests were used to compare the distribution of choices across the three alternatives. Where only two alternatives were presented, a binomial test, using the normal approximation, was employed, and a Z-score, rather than a chi-square, appears in the table. As the figures indicate, there were significant differences in preference among symbols for all but two referents (General Warning and Eyewash).

Before discussing each set of symbols in detail, some general conclusions can be made about the results. First, despite the pre-selection of symbols based on expert rankings, there were often wide differences in the degree to which different symbols communicated the same message. The Corrosion Hazard and Entanglement Hazard Symbols provide some examples. Secondly, some referent messages appear much more difficult to convey than others. In some cases no alternative was well understood (e.g. No Exit, only 18-59 percent at least partially correct) while in other cases, all alternatives were well understood (e.g. Eye Protection, 90-100 percent for at least partially correct). In general, protective gear messages appear relatively easy to indicate symbolically.

Understandability and preference were sometimes dissociated. Where the understandability data indicated a clearly superior symbol (eg., Safety Shower Location), that alternative was usually preferred. Yet, there was occasionally a strong preference for a particular symbol even where little difference in the understandability measure existed; infrequently, a strongly preferred alternative was the most poorly understood (eg. Foot Protection Required).

In general, industrial and non-industrial participants yielded similar patterns of results (due to differences in symbol sets and procedure, no formal statistical comparisons were made). Some exceptions are noted in the following sections.

Partially correct and incorrect answers were analyzed to reveal common errors for each symbol. These results are summarized in table 1 of appendix C. The preference answers were reviewed to find common reasons for preferring or disliking each symbol. These findings are summarized in table 2 of appendix C.

5.2 DISCUSSION OF SPECIFIC FINDINGS

5.2.1 Overview

Figures 1 through 31 present detailed analyses of the responses for both groups of subjects to each symbol. These not only include a breakdown of the understandability and preference measures for each symbol, but also a summary of the common errors and preference reasons. Data for percentage fully correct responses, percentage correct plus partial (lenient category), percentage wrong, and percentage no answeres are presented, along with the percentage of a particular subset of answers where these were of additional interest. The most frequently occurring wrong answers for industrial subjects are presented, for those wrong answers which occurred more than once for a particular image. The percentage of "critical confusions" for industrial subjects is also indicated on this tabulation. These are derived from the number of wrong answers given by all subjects responding to a specific image, and are defined as an opposite--to-correct or seriously inappropriate answer. The chi-square statistics for industrial subjects are also presented for both understandability and preference data. The lower portion of the figures present percentage preference data for both groups of subjects, and the most frequently occurring preference reasons for industrial subjects. While the stated reasons for preferences are ofen informative, some subjects had considerable difficulty expressing their reasons; "no reason" was often the most frequently occuring response.

The data presented in figures 1-31 are discussed in detail in the following sections. Comparisons are made between images for a given referent and for images within a generic category (such as hazard warnings or protective gear requirements). Comparisons are also made between industrial and naive groups of subjects. In the discussion, reference is made to the ISO criterion cut-off. ISO (referenced in AS 2342, 1980) proposed a level of 85 percent correct responses on an understandability test as the cut-off between acceptable and non-acceptable symbols. It also proposed that symbols for which five percent or more critical confusions are elicited are not acceptable, regardless of the percentage of correct answers. The data in the following pages are discussed

in terms of their performance related to these ISO criteria. These criteria themselves are not addressed, although there may well be conditions in which the severity of the indicated hazard could mean that a cut-off of 85 percent is too low. In this report the criteria are used as an arbitrary point for discussion purposes only. Further research is needed to determine whether these criteria are the most appropriate.

5.2.2 Hazard Warning Messages

Figures 1-12 all concern referents that indicate hazard warnings. These will be considered first.

Figure 1 presents the data obtained for three images for electrical hazard. Image C, of hand and wire, emerges as the best understood and most preferred image for both industrial and naive participants. The understandability of image C is even greater if answers involving wires are included in the correct plus partial category increasing this from 74.4 to 96.5 percent correct. Answers involving electric wires were identified separately for the main experiment because of some concern that image C too explicitly referred to exposed electrical wires and the actual hazard might occur in some other form. Even without consideration of such answers however, image C is significantly more understandable than image A, the internationally proposed symbol for electrical hazards. In addition, symbol A received a number of wrong answers unrelated to electrical hazards, including curved or crooked road, slippery floor, and danger, or go below. Wrong answers for image B were restricted to ideas about lightning and for image C to ideas about hand danger.

The preference data for all participants indicates a clear preference for image C because of the hand and wire and explicit rendition of electric hazards to people. Image A was chosen because of its color and shape while image B was believed to "look like electricity." Image C is somewhat unusual in that "no reason" for this choice is the third, rather than first most frequently occurring answer. Participants remarked on the graphic characteristics of image C and its depiction of hazard as the primary reason for their choices. Image C thus emerged as the most successful depiction of electrical hazard, of the three images studied.

Figure 2 presents the data obtained for three images for explosion hazard. These images varied in terms of their abstractness as well as in color and surround shape. Chi square tests for industrial personnel revealed a significant difference in the understandability data for the three images, with image B having the highest percentage of fully and partially correct answers. Naive participants provided more fully correct answers for images B and C but were generally quite similar for the lenient (correct plus partial) category. Wrong answers for the three images included ideas of flammability, danger, and broken glass for images A and C, electricity for image B, and flying stones for image C. Image A also received answers such as "star" that were unrelated to any sort of hazard. Both images B and C were understood by more than 80 percent of the subjects if lenient scoring criteria are used.

Figure 1. Danger, electrical hazard

	A	B	C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
Correct - C	47.9	62.5	69.8
Lenient - C+P	63.9	77.3	96.5
Wrong - X	29.8	13.6	3.49
No Answer - N	6.4	9.1	0
	1.1[1]	2.3[1]	22.1[1]
X^2 (Chi square)	X^2=39.78, df=4, p<.001		
Naive	N = 53[2]	N = 54	N = 61
C	28.3	61.1	86.9
C+P	37.7	66.7	95.1
X	54.7	31.5	4.9
N	7.5	1.8	0.0
Wrong Answers	lightning curves crooked road danger below slippery floor go to lower level	lightning	hand danger
PREFERENCE DATA			
Industrial	9.0%	11.3%	79.3%
X^2	X^2=213.39, df=2, p<.001		
Naive	6.4%	3.3%	89.8%
Reasons	no reason color & shape more noticeable	no reason, looks like electricity large & clear	hand & wire wire shows electrical hazard no reason better graphics explicit

[1] Includes answers specific to electric wires - included in C&P category.

[2] Forty-five subjects saw all symbols.

Figure 2. Danger, explosive hazard

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 94	N = 86
C	56.8%	64.9%	54.6%
C+P	71.6%	88.3%	82.5%
X	15.9	7.5	9.3
N	12.5	4.3	8.1
X^2	X^2=11.6, 4df, p<.05		
Naive	N = 54	N = 53	N = 61
C	55.6%	83.0%	65.6%
C+P	66.7%	88.7%	90.2%
X	29.6%	11.3%	8.2%
N	3.7%	0	1.6%
Wrong Answers	fire, combustible beware of broken glass star danger, disaster area	flammable, fires high tension electricity danger, hazard area	breakable, shattered glass flying stone, gravel
PREFERENCE DATA			
Industrial	4.7%	38.3%	56.1%
X^2	X^2=91.43, df=2, p<.001		
Naive	1.3%	39.7%	57.7%
Reasons	no reason more noticeable	no reason, looks more like explosion clearer, more vivid color	no reason, looks more like explosion debris shape, color imply caution more easily understood best sign

Both groups of participants expressed a preference for C, the ISO proposed image. Reasons for the selection included the idea that it looked more like an explosion with flying debris, its background shape and color implied caution, and it was the best, most understandable sign. Image B was selected because it looked more like an explosion, was clearer, more vivid and was red, while image A was claimed to be more noticeable. For all three images, however, "no reason" was the most frequently occurring answer for the preference choice.

Figure 3 presents three images for flammable hazard. All images tested below 85 percent correct for all subjects, and no significant differences between the three images emerged. The reasons for the poor performance can be seen from the wrong answers, which generally suggest the idea that fire or high temperatures are present or permitted in the area. These symbols do not seem to convey successfully the idea of combustibility--that something could ignite, rather than that something is burning. In particular, image B conveyed the idea of fire permitted to six percent of those studied--an example of a "critical confusion."

These data suggest the need to improve the currently proposed images for combustible hazards to increase the awareness of possible flammability rather than presence of an actual fire. Use of red color, as in image C, does not appear to do this, nor does the triangle or yellow color in images A and B. Training people on the meaning of a flammable hazard symbol may be needed to convey the idea that something could burn. The preference data are about evenly split between images B and C, with clarity, color and visual rendition given as primary preference reasons. No symbolic image emerges as particularly successful in communicating the idea of flammability. In the absence of a successful image for flammability hazards, users might consider the use of a prohibition symbol, such as "No Open Flame" or "No Smoking."

Figure 4 presents the data for three images for corrosion. The pattern of responses for both naive and industrial subjects was very similar. Image B, the bandaged hand, was clearly not understood by the majority of the subjects. Image A, the ISO proposed image, was the only image performing above 85 percent for leniently scored data. (A also received very few wrong answers.) For image B, 45 percent of the answers were related to first aid or bandaged hands. Turning or stopping, pinch points, danger and hand injuries were also frequently given answers. For image C, 79 percent of the answers referred to first aid or emergency hand wash while sharp cutting machinery was also given as a wrong answer. Image B was not only not understood, it was often perceived as emergency aid rather than a hazard. On the other hand, only two percent of the answers to image A were related to emergency aid.

The preference data for all subjects indicated a strong preference for image A as the best depiction of corrosion hazard. Reasons included that it was clearer and more believable, showed consequences, showed two types of hazard, portrayed chemicals dripping, and its color (yellow) and shape (triangle). Image C was selected because it showed a larger concentration of effect and was more descriptive. No subject expressed a preference for image B. Image A thus emerged as the most understandable and preferred of the images tested for corrosion as well as having the least number of opposite and potentially hazardous confusions.

Figure 3. Danger, flammable

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	41.5%	41.9%	52.3%
C+P	70.2	65.2	65.9%
X	19.1	34.9	31.8
N	10.6	0	2.3
X^2	X^2=6.68, df=4, NS (not significant)		
Naive	N = 53	N = 61	N = 54
C	34.0%	41.9%	52.3%
C+P	64.2%	65.2	65.9%
X	30.2	45.9	29.6
N	5.7	0	0
Wrong Answers Confusions	fire present in area, hot, high temperature smoking area	fire present in area, fire extinguisher fires permitted - 76.6%	fire, open flames extreme heat watch for fire
PREFERENCE DATA			
Industrial	5.4%	50.9%	41.9%
X^2	X^2=78.72, df=2, p<.001		
Naive	5.1%	44.9%	48.7%
Reasons	no reason	no reason, clearer, easier to distinguish color & shape looks like fire should be red	no reason red color good visual rendition clearer

Figure 4. Corrosion hazard

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 86	N = 94
C	78.4	1.2	69.1
C+P	90.9	18.6	80.8
X	3.4	63.9	13.8
N	5.7	17.4	5.3
X^2	X^2=137.58, df=4, p<.001		
Naive	N = 54	N = 61	N = 53
C	74.1	6.6	75.5
C+P	92.6	18.1	83.0
X	5.6	73.8	16.9
N	1.9	8.2	0
Wrong Answers		Danger, pinch points Turn (left, right) danger, think stop, halt	caution sharp cutting machinery
Confusions	*First aid, hand wash 2%	*First Aid bandaged hand, injuries 73%	*emergency hand wash area 4% *first aid - 3%
PREFERENCE DATA			
Industrial	78.2	1.8	17.8
X^2	X^2=220.96, df=2, p<.001		
Naive	64.1	0	32.0
Reasons	no reason clearer, more believable shows consequences color & shape two types of hazard chemicals dripping	no reason	no reason larger concentration of effect more descriptive

Figure 5 presents the data obtained for two images studied for poison. Not only was image A, "Mr. Yuk", not understood, many of the answers were frivolous or inappropriate. Ten percent, for example, were related to unhappy people or unpleasant areas. While image B, the skull and crossbones, was correctly identified by only 76 percent of those tested, wrong answers referred to danger or death rather than "cafeteria ahead" or "have an unhappy day." "Mr. Yuk", however, is one image for which the naive participants performed substantially better (52 percent vs. 20 percent for leniently scored data) than the industrial participants. These participants were generally younger and may have seen some of the television and other advertising aimed at teaching children that "Mr. Yuk" means poison. Nevertheless, image B was still identified correctly by more of these participants (82 percent vs. 52 percent). Neither of the two poison images reaches the 85 percent criterion cutoff, unless the general references to danger and death are counted as correct for image B.

The preference choice was clearly for image B, although the naive participants expressed a slightly greater liking for Mr. Yuk than did the industrial participants (20 percent vs. four percent). The only reason given for selecting Mr. Yuk is that this symbol would be more clearly recognized by children (not a significant concern for industrial conditions). The skull and crossbones was selected because it was widely known and recognized, presented the idea of death and skeletons, had more impact, and depicted poison. Further consideration of "Mr. Yuk" for industrial participants appears inappropriate based upon the significant understandability and preference data for the skull and crossbones presented in figure 5.

Figure 6 presents the data for three images for entanglement. These images varied widely in understandability, with only image C, hand and gears, performing above 85 percent for leniently scored data for both groups of participants. Using lenient criteria, image A also scored above criterion levels for naive but not industrial participants. In terms of wrong answers, a greater percentage of people gave "machinery in use" as an answer for image A than for image C (15 percent vs. one percent). Image B was poorly understood for all participants with wrong answers related to movement, explosives, machinery in use, intersections and the like. The presence of the hand in image C appears to convey the message of "machine hazard" rather than simply "machine in operation."

The preference data strongly favored image C because it showed the consequences, was easy to visualize, and looked painful. Image A was selected because it showed open gearing, while no reasons were given for selecting image B. For image C, "shows consequences" occurs even more frequently than "no reason." For entanglement hazards, then, image C, hand in gears, emerged as the most well understood and most preferred for all participants tested.

Figure 7 presents data for three images for slip hazards. All images performed above the 85 percent cut-off, regardless of scoring criterion (lenient or strict) for industrial personnel. (Only image A falls below this for naive subjects). Furthermore, there was no significant difference between the images in terms of understandability for industrial participants. Wrong answers for image

Figure 5. Danger, poison

A B

UNDERSTANDABILITY DATA		
Industrial	N = 86	N = 88
C	13.9%	75.0%
C+P	19.7	76.1
X	43.0	21.6
N	37.9	2.3
X^2	Z=62.87, df=1, p<.001	
Naive	N = 61	N = 54
C	45.9%	75.9%
C+P	52.5	81.5
X	45.9	18.5
N	1.6	0
Wrong Answers	gas, fumes in area caution, bad taste, bad food unhappy people, unpleasant area danger, caution hazard, vomit area	danger
Confusions	*smile, good attitude 2%	
PREFERENCE DATA		
Industrial	4.5%	94.1%
X^2	z=6.20, p<.001	
Naive	20.5%	79.5%
Reasons	no reason more clearly recognized by children	no reason widely know & recognized idea of death, skeleton best, more impact shows poison

Figure 6. Danger, entanglement hazard

	A	B	C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	67.0%	30.2%	77.3%
C+P	82.9	36.2	94.3
X	15.9	33.7	1.1
N	1.1	30.2	4.5
X^2	X^2=81.96, df=4, p<.001		
Naive	N = 53	N = 61	N = 54
C	45.3%	9.8%	63.0%
C+P	90.6	19.6	94.5
X	9.4	63.9	5.6
N	0.0	16.4	0.0
Wrong Answers	Machinery in use, 15%	turning rolling objects think, danger, caution intersection, no U turn explosives in use going both ways moving fast turn around machines in area protective eye gear needed	machinery area 1%
PREFERENCE DATA			
Industrial	11.5%	5.9%	81.8%
X^2	X^2=240.39, df=2, p<.001		
Naive	10.2%	0	88.5%
Reasons	no reason shows open gearing	no reason	show consequences no reason easy to visualize looks painful

Figure 7. Danger of slipping

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	94.2%	93.2%	87.2%
C+P	94.2	94.2	90.4
X	5.8	3.4	6.4
N	0	2.3	3.2
X^2	X^2=3.87, df=2, (non-significant)		
Naive	N = 61	N = 54	N = 53
C	77.0%	81.5%	94.3%
C+P	81.9	90.8	96.2
X	14.8	9.2	3.8
N	3.3	0.0	0.0
Wrong Answers	wear boots snake may bite	housekeeping, keep area clear	dock, ledge area
PREFERENCE DATA			
Industrial	9.5%	37.8%	52.7%
X^2	X^2=64.3, df=2, p<.001		
Naive	10.2%	33.3%	56.4%
Reasons	no reason shows hazard	no reason person falling clear, more understandable	no reason shows falling clearest

A included "wear boots" and "snake may bite," for image B, "keep area clear," and image C, "dock" or "ledge area." None of these answers included serious confusions or opposite meanings.

Consideration of the preference data revealed a strong preference for version C, because it showed the whole body falling and was the clearest. Despite good understandability, only about 10 percent of those responding chose image A, stating that it showed the hazard. Image B was selected because it showed the idea of falling and was more understandable. Image C thus appears to be the best portrayal of "slip" hazard based upon the preference and understandability data although none of the three images elicited any critical confusions.

Data for slip hazard given in figure 7 must be considered in conjunction with those given in figure 8 for tripping and falling hazards. The very poor performance of image B of figure 8 was due to a large number of answers related to slips. About 70 percent of those responding believed that image B represented a slipping hazard. Image B of fall hazard (figure 8) and image C of slip hazard (figure 7), which differ only in the presence of a horizontal surface in image C, both successfully conveyed the message of "slip" to 70 to 90 percent of those tested. Image A of figure 8 conveyed the idea of tripping and falling along with obstructions in the path of travel. Image C conveyed the idea of fall from elevation to 72 percent of those responding and the idea of falling over to another 20 percent. It did not convey the idea of tripping over an object, however. Consideration of the understandability data, including wrong answers, for figures 7 and 8, suggests the need for three separate referents--slipping hazard due to slick surfaces, tripping hazard due to obstructions in the path of travel, and falling hazard due to sudden changes in elevation.

The preference data for the fall symbols indicated a preference for B because it showed the person falling and was clearest, although the same reasons were also given for C. A was selected for "no reason" and because it showed the hazard. Because at least two ideas were clearly being responded to here, it is a bit difficult to conclude that one image represents tripping and falling better than another. Participants, whether naive or informed, clearly differentiated between tripping, falling, and slipping as three unique ideas and images. Subsequent research should separate these three referents and determine if three distinct images can uniquely convey the messages of slip, trip, and fall.

Figure 9 presents data for three images for fork lift truck hazard. Images A and C tested above the 85 percent criterion level for both naive and informed subjects for leniently scored data. Image B, which performed more poorly, conveyed ideas about men working, suggesting that the forklift driver should watch out for people working. The presence of two figures in the image caused confusion about what the hazard really is--the person working or the forklift truck moving. Other comments were related to the work done by the forklift. Image A received few wrong answers, all related to the need to use or not use a forklift, while image C received more wrong answers, again related primarily to forklift operation. In general, naive participants performed somewhat more poorly perhaps due to their lack of familiarity with forklift trucks.

Figure 8. Danger of tripping or falling

	A	B	C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	69.8%	14.9%	20.4%
C+P	90.7	17.0	92.0
X	6.4	6.4	2.3
N	6.4	6.4	5.7
	slip 3.5	slip 70%	fall 71.6%
X^2	X^2=127.01 df=4, p<.001		
Naive	N = 61	N = 53	N = 54
C	78.7%	26.4%	51.8%
C+P	91.8	28.3	87.0
X	8.2	15.1	13.0
N	0.0	0.0 slip = 56.6%	0.0
Wrong Answers	boots safety shoes required	hazard, danger area	
PREFERENCE DATA			
Industrial	20.3%	50.5%	25.2%
X^2	X^2=36.37, df=2, p<.001		
Naive	14.1%	43.6%	38.5%
Reasons	no reason shows hazard	no reason person falling clearer, more understandable	no reason shows falling clearest

Figure 9. Danger, fork lift operating in area

A B C

	A	B	C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	83.0%	54.5%	72.1%
C+P	96.8	81.8	93.0
X	2.12	15.91	6.98
N	1.06	2.27	0
	slip 3.5	slip 70%	fall 71.6%
X^2	X^2=21.02 df=4, p<.001		
Naive	N = 53	N = 54	N = 61
C	64.2%	42.6%	67.2%
C+P	92.5	81.5	88.5
X	1.9	1.9	11.5
Wrong Answers	handle, don't handle with fork lift	watch for men working dangerous work area use truck lift	forks in improper location
PREFERENCE DATA			
Industrial	59.7%	31.1%	8.3%
X^2	X^2=89.00, df=2, p<.001		
Naive	57.7%	34.6%	7.7%
Reasons	no reason clearest, most understandable person & truck looks more like fork lift shape & color	no reason red means danger most informative	no reason easiest to understand

Image A was most preferred by both groups of participants. They stated that it was clearest and most understandable, showed a person and a truck, looked more like a forklift and was the right background shape (triangle) and color (yellow). Image B was selected because it was red and was most informative (despite the fact that participants did not understand it as well). Image C was chosen least frequently, although some participants claimed it was the easiest to understand. Image A, of a person driving a fork lift, emerges as the best understood and most frequently preferred, although image C was also well understood.

Figure 10 presents data for three images for overhead hazard. These images varied from very abstract (A) to representational (of the hazard - B), to a rendition of the consequences of the hazard (C). Image A, the most abstract image, was not understood, either by naive or industrial participants. For image B, 60 percent of those tested identified it as overhead hazard with about another 35 percent identifying it specifically as crane load or broken cable. Similarly, image C conveyed the idea of wear hard hat (to 44 percent of the participants) almost as well as overhead hazard (51 percent). Images B and C thus appeared to be providing very specific meanings directly related to the hazard or action depicted. The more abstract, general image, A, was even less successful, conveying ideas of yield, caution, hole, objects on floor, fallout shelter, hazardous materials, radiation, dark area, and a host of other inappropriate responses.

Participants expressed a strong preference for image B saying that it represented an overhead hazard and was clearest. Image C was the second choice because it made the consequences clear with an object falling on a person. Image A was selected by only 0.5 percent of the subjects.

Overhead hazard appears to be another referent for which the intended meaning must be more clearly defined. A broken crane load is perceived as just that, not as a more general overhead hazard. Image C effectively conveys the message of wear hard hat but may not warn of moving, heavy loads overhead, for which a hard hat would be insufficient protection. The two images, B and C, appear to present two distinguishable messages, while image A does not communicate, much, if any useful hazard warning information.

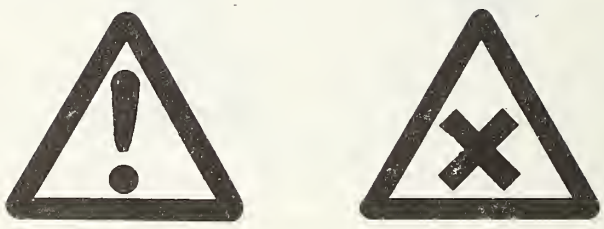
Figure 11 presents data on two images for general warning. Neither image is well understood, with B being particularly unsuccessful (eight percent lenient category). The naive participants did appear to understand A somewhat better (79 percent versus 56 percent, lenient) than did the industrial participants for reasons that are not clear. Wrong answers for A included ideas such as stop, ballpark, excitement, overhead operation, and information. Wrong answers for B indicated that participants associated it with crossings, intersections, and prohibited actions (do not enter, do not yield, do not proceed, and do not touch). Although A was preferred to B, at least 30 percent of those tested chose neither image, and where a choice was made, the most frequently occurring comment indicated that both images were poor. The exclamation point in A was seen as providing some idea of "pay attention" while the X in B indicated "stop". Nevertheless, if a general warning symbol is believed to be useful, some form of further training on the meaning of either A or B would be required.

Figure 10. Danger overhead hazard

A B C

UNDERSTANDABILITY DATA			
Informed	N = 88	N = 94	N = 86
C	2.3%	52.1%	51.2%
C+P	3.4	59.5	95.4
X	52.3	5.3	1.2
N	44.3	0	3.5
		crane load = 35.1%	
X^2	X^2=217.77, df=4, p<.001		
Naive	N = 54	N = 53	N = 61
C	5.6%	67.9%	54.1%
C+P	5.6	73.6%	90.2
X	85.2	17.0%	8.2
N	9.2	0.0	1.6
		crane load=9.4%	
Wrong Answers	yield danger, caution area going down, hole something on floor toxic, hazardous radiation limited visibility fallout shelter	broken cable, bad strap	
PREFERENCE DATA			
Industrial	0.5	69.6	30.0
X^2	X^2=160.34, df=2, p<.001		
Naive	1.3	52.6	44.9
Reasons	simple	no reason shows overhead hazard depicts hazard better clearest, easy to understand	no reason object falling on person consequences clear more understandable

Figure 11. General warning



A B

	UNDERSTANDABILITY DATA	
Industrial	N = 94	N = 88
C	51.1%	6.8%
C+P	56.4	7.9
X	13.7	71.6
N	29.8	20.5
X^2	Z=40.55, df=1, p<.001	
Naive	N = 53	N = 54
C	62.3%	5.6
C+P	79.3	7.5
X	15.1	90.7
N	5.7	1.8
Wrong Answers	stop ballpark excitement area overhead in operation information/exclamation area	restricted area, keep out, no entry dangerous crossing, intersection dead end, no access, right of way do not yield do not proceed, cross unsafe, do not touch do not
	PREFERENCE DATA	
Industrial	40.1%	29.7%
X^2	Z = 1.85, N.S.	
Naive	44.9%	30.8%
Reasons	no reason neither one easily understood exclamation point	no reason both bad indicates stop more understandable

Image A appears to be a somewhat more promising choice in that 56 percent understood it versus the eight percent (lenient scoring) who understood B. Yet, neither symbol is particularly successful in communicating the idea of "watch out, pay attention, and general hazard warning." In fact, the skull and crossbones image of figure 5 is almost as effective at conveying the idea of possible danger or death.

Figure 12 presents understandability data for three referents - radiation (A), laser (B) and biohazard (C). Each of these has been standardized at least briefly by OSHA, while the radiation symbol has been in use for many years. The data however, indicate that none of these symbols reach a criterion level of 85 percent understandability, with laser and biohazard being at or below 25 percent. Wrong answers for radiation included numerous confusions about fans, blades, moving parts, alarm, and noise as well as a critical confusion with fallout shelter for three percent of the industrial participants, and 11 percent of the naive subjects. This is a serious misidentification which could lead people into, instead of away from the hazard. It may be due to the current similarity of colors between the radiation and fallout shelter symbols. ANSI Z53 recently standardized (1980) the radiation symbol as yellow and black, with black replacing the magenta previously used for radiation. The fallout shelter symbol is also a yellow and black abstract 3-part symbol (within a circular surround). These critical confusions associated with the radiation symbol are potentially serious, because the air raid symbol/fallout shelter symbol is intended for public information, and because the radiation symbol is used on consumer products such as smoke detectors and fire alarms.

The laser and biohazard symbols were even less well understood than the radiation symbol. The biohazard symbol was deliberately designed not to be meaningful (Baldwin and Runkle, 1967). It was felt that a unique but memorable symbol could be taught and used to indicate situations where warning of potential infection hazards is needed. Certainly the present data reconfirm those of Baldwin and Runkle indicating that the symbol does not communicate meaningful information. If this symbol is to be useful, extensive training will be needed for the intended audience and the symbol must not be used to convey information about potential hazards to the general public or to any non-trained audience.

Similar remarks apply to laser, which did not communicate successfully on its own. In fact both the laser and biohazard symbols communicated the idea of radiation to about 10 percent of those tested. Training and supplementary word signs are needed for each of these three messages if these symbols are used. Along with image A for overhead hazard, image B for entanglement and the two images for general warning, these three images are among the most abstract studied in the present experiment. None of the seven abstract images tested were very successful at communicating their intended message, and clearly require training and auxiliary signage to communicate successfully. Informal exposure such as the lengthy use of the radiation symbol is not sufficient judging by the relatively poor performance of this particular symbol. In any situation, where one of these symbols might appear on a consumer product or public space, auxiliary hazard information must be provided to ensure the safety of the user.

Figure 12. Three specialized hazards

	Radiation A	Laser B	Biohazard C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	58.5%	1.1%	0 %
C+P	65.9	25.0	1.2
X	34.0	38.7	46.5
N	0	36.4	52.3
Naive	N = 53	N = 54	N = 61
C	30.2%	5.6%	3.3%
C+P	30.2	25.9	3.3
X	56.6	61.1	72.1
N	13.2	7.4	24.6
Wrong Answers	caution fans, blades ventilation system, fan moving parts, shaft hearing protection, noisy area siren	radiation area caution sunshine explosion, explosive caution, welding high voltage, wires solar energy plant snow area flying debris no light allowed	radiation blades, rotating object flying, falling objects sharp cutting objects moving machinery parts heavy machinery space craft multiple outlets emergency area, vehicles intersection
Confusions	*fall out shelter 3%		

Consideration of the data on hazard symbols summarized in figures 1 through 12 suggests that symbols which include both the hazard and a person will be the most likely to be correctly defined. Furthermore, participants generally preferred this style of representation and stated that it is most effective. The only exception was a symbol for overhead hazard in which the image of a crane load without a human figure was preferred.

Although some preference for yellow and the triangle as background shape was expressed, these features did not appear to affect understandability in any substantial way. In four cases, flammable, corrosion, slip, and forklift, the symbol with the highest percentage of correct plus partial answers was shown as yellow with the triangular surround shape. In five cases, however, explosion, electricity, entanglement, fall, and overhead hazard, the "best" symbol was presented as black and white in a square surround. Participants appear to have responded primarily to the image content rather than the surround and color. They did, however, indicate in comments in the preference section, an awareness of the common practice of the use of a triangle to indicate hazard, yellow to indicate caution, and red to indicate danger. Of course, features such as surround shape and color were not systematically varied or studied in the present study. Any deductions about their effectiveness remain purely inferences.

In five cases, explosion, corrosion, poison, fork-lift, and general warning, the ISO/EEC proposed image was the best understood. Images for other ISO referents which did more poorly included electricity, flammable, overhead hazard, laser, and radiation. Entanglement, slip, fall, and biohazard are not included in current ISO recommendations. The ISO images may tend to be somewhat more familiar in that many of these are used on the DoT/UN hazard materials transport placards. Yet, it is interesting to note that the images for electricity and flammable hazards did not perform particularly well despite their widespread use. These data reinforce the need to determine the understandability of hazard warning images before standardization or widespread use.

Referents for which no image reached an 85 percent criterion level of performance for either strict or lenient scoring categories included radiation, laser, biohazard, flammable, poison and general warning. Flammable and poison were the best understood of these, performing at about the 75 percent level. For all other hazard referents, at least one image met the ISO criteria of 85 percent correct response and fewer than five percent critical confusions.

In general, symbols in the other referent categories received a higher percentage of correct answers than did the hazard warning symbols. Although each category will be discussed in detail, the protective gear and safety message images were quite well understood. Only the egress-related messages caused understandability problems as serious as some of the hazard warning messages.

Figure 13. No open flame

A B C

UNDERSTANDABILITY DATA			
Informed	N = 86	N = 88	N = 94
C	68.6%	73.9%	71.3%
C+P	90.7	95.5	95.8
X	5.8	3.4	3.2
N	3.5	1.1	1.1
X^2	X^2=2.73, df=4, NS		
Naive	N = 61	N = 54	N = 53
C	70.5%	87.0%	71.7%
C+P	93.5	98.1	96.2
X	6.6	1.8	3.8
N	0.0	0.0	0.0
Critical Confusions	*fire, open flames 4.7% *no fire hazard 1.2%	*watch out for fires 1.1%	*fire 2.1%
PREFERENCE DATA			
Industrial	42.6%	45.7%	8.6%
X^2	X^2=58.39, df=2, p<.001		
Naive	50.6%	45.5%	3.8%
Reasons	no reason excludes all flames clearer, easier to see & understand depicts flame better	no reason more graphic, visible shows no open flame better shows matches, beware easiest to understand	no reason easiest to understand match clearer

5.2.3 Prohibited Action Messages

The category of prohibited actions, including no smoking and no open flame contains images that generally were defined correctly. For "no open flame," figure 13 reveals that for lenient scoring all images tested above 90 percent correct. Image A created some problems with 5.9 percent of the industrial personnel responding that it meant fire, open flames, or no fire hazard, each a critical confusion. Both images B and C received only one to two percent critical confusions. Data for industrial and naive participants were similar although the naive people performed slightly better.

Generally, industrial participants preferred version B, while naive participants preferred image A. Image A was preferred because it excluded all flames, while image B was believed to be more graphic or visible. Image B, because of the lack of critical confusions, good understandability data, and industrial preference would appear to be a good representation of "no open flame," at least for industrial applications. Image C was selected by very few people.

Figure 14 presents data for "no smoking" for which both images did equally well, for both participant groups with no critical confusions. Image B was selected as the most appropriate image by a significant majority of those tested. Its clarity, contrast, and good graphics were among the major reasons for this choice.

The use of the circle and slash now appears to be a meaningful way of indicating prohibition. When Brainard et al. (1961) conducted their research two decades ago, this symbolic convention was not well understood in the U.S. Data from the present experiment, and from one by Lerner and Collins (1980) indicate that subsequent public exposure has been sufficient to "teach" the meaning of the circle and slash reasonably well.

5.2.4 Safety and Fire Emergency Messages

The safety messages tested included first aid, safety shower, and eyewash. Both images for first aid (fig. 15) were well understood, above the 85 percent criterion for lenient scoring, with no significant difference in understandability between the two. Wrong answers for image A included safety, cross roads, and red cross, while wrong answers for image B included "watch fingers" and hand safety. Image A was chosen significantly more frequently as appropriate by industrial personnel because of its existing standardization and link to the idea of medical assistance. Image B which includes the cross, represented the idea of completed first aid to a minor injury. Naive participants saw little difference between images A and B. Because of good understandability and general industrial preference, image A, the cross, appears to be a good candidate symbol for first aid.

Figure 16 presents data for safety shower, for which only one image, B, performs above criterion for leniently scored data (although image C is close). In all cases, the difference between strict and lenient scoring is due to failure to specify "safety shower." Participants were aware that the image related to

Figure 14. No smoking

A

B

UNDERSTANDABILITY DATA		
Industrial	N = 94	N = 86
C	96.8%	96.5%
C+P	97.9	96.5
X	1.1	2.3
N	1.1	1.1
X^2	Z=0.20, df=1, NS	
Naive	N = 53	N = 61
C	96.2%	96.7%
C+P	98.1	98.4
X	1.9	1.6
N	0.0	0.0
Wrong Answers		
PREFERENCE DATA		
Industrial	35.1%	55.4%
X^2	Z = 3.17, p<.01	
Naive	28.2%	71.8%
Reasons	no reason better graphics cigarette more realistic	no reason stands out, more visible looks more like cigarette black on white background

Figure 15. First aid

A

B

UNDERSTANDABILITY DATA		
Industrial	N = 94	N = 86
C	82.9	88.4
C+P	87.1	91.9
X	11.7	8.1
N	1.1	0
X^2	Z=0.67, df=1, NS	
Naive	N = 53	N = 61
C	90.6	86.9
C+P	94.4	93.5
X	5.7	6.6
N	0.0	0.0
Wrong Answers	safety crossroads, intersection white, red cross	watch fingers, danger hand safety
PREFERENCE DATA		
Industrial	59.0%	39.6%
X^2	Z = 2.91, p<.01	
Naive	46.8	53.2
Reasons	no reason standard sign medical assistance red cross	no reason shows completed first aid shows minor, hand injury best, better understood

Figure 16. Safety shower location

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	47.9%	60.5%	46.6%
C+P	76.6	98.9	84.1
X	20.2	1.2	9.1
N	3.2	0	6.8
X^2	X^2=200, df=4, p<.001		
Naive	N = 53	N = 61	N = 54
C	26.4%	60.9%	31.5%
C+P	66.0	99.9	85.2
X	30.2	0.0	14.8
N	3.8	0.0	0.0
Wrong Answers	sprinkler system control falling water, wet area		sunlamp, bright lights watch for falling objects shower room, bathroom
PREFERENCE DATA			
Industrial	1.4%	83.8%	14.9%
X^2	X^2=260.35, df=2, p<.001		
Naive	1.3%	75.6%	23.81%
Reasons	no reason good but lacks person clarity	no reason more information, detail person using shower clear, most understandable shower clear relates better to safety	no reason clearer, more understandable graphic, more visible good contrast

water or shower; they did not always express its relation to safety. Only image C elicited responses unrelated to water, such as lights or falling objects. Image B was preferred by both groups because it provided the most information, showed actual use, had a person fully clothed, and generally was clearer and related better to safety. This symbol could suffer, however, from very poor legibility due to its extreme complexity.

Figure 17 presents data on three images for eyewash location. This referent is one of the few for which no significant difference between images occurred for either the understandability or preference data. The percentage of correct responses for each image was about 65 percent regardless of scoring criterion while the percentage of industrial personnel choosing each image was about 31 percent. The percentage of correct responses was lower for all images for naive participants, who are less likely to have been exposed to an industrial eyewash. These people also expressed a preference for image C. Lack of familiarity with an eyewash may account for the large number of wrong answers associated with eye irritant, hazardous material splashing, and eye protection needed. Only image A, the most directly representational image, did not elicit a large number of these opposite confusions. The preference data indicate that image A was preferred because it shows the eye and water and was clearer, while image C was selected because the eye and fountain were clearer and the eye was more realistic. Nevertheless, none of these images was particularly successful in conveying the message of eyewash.

Of the symbols for safety related referents, only those for eyewash did not reach criterion level, perhaps due to lack of familiarity with this equipment (which is needed only where chemical irritants are used.) Use of the color "green" for all of these images elicited no comments nor did the use of a square background shape. Two people did comment that the cross should be red--for red cross. The one abstract safety image, a cross, was well understood, probably because of its widespread use for centuries to represent aid or help.

Figures 18 and 19 present data for fire emergency referents, including extinguisher, hose and reel connection, and fire alarm call point. Both fire extinguisher and hose and reel, figure 18, were correctly defined above the 85 percent criterion level. Performance on these two symbols for lenient scoring criteria was very similar to that reported by Lerner and Collins (1980). Since only a single symbol was tested, no preference data were obtained for either of these two messages. Fire alarm call point, figure 19, created a number of problems, due to confusion about the intended message. It was intended to mean "fire alarm call point," or the location where an alarm is turned in. Many people, however, treated it as "fire alarm" or the location of an alarm sounder to warn building inhabitants of a possible fire. As a result, answers referring only to "fire alarm", or "fire phone" were identified separately and amounted to 17 percent of the answers for image A, 50 percent of the answers for image B, and 90 percent of the answers for image C. Inspection of figure 19 reveals that most participants did not respond with ideas of "fire alarm call point", (as the data were scored for industrial personnel) for any of the images. Furthermore, images A and B elicited a large number of answers related to noise, ear protection, school, church, wheels, and rotating shafts.

Figure 17. Eyewash location

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	64.9%	63.6%	62.8%
C+P	67.0	64.7	64.0
X	19.1	23.9	32.6
N	13.8	11.4	3.5
X^2	X^2=0.08, df=2, NS		
Naive	N = 53	N = 54	N = 61
C	34.0%	40.7%	49.2%
C+P	56.6	46.3	55.8
X	44.4	46.3	45.3
N	0.0	7.4	0.0
Wrong Answers	water fountain eyes & nose running overhead hazard area weighing scales		splashing 14% someone watching you
Confusions	watch for eyes & mouth 2%	eye irritation, danger 12.5% wear eye protection 12.5%	eye protection should be worn 18.6% eye hazard, material splashing 14%
PREFERENCE DATA			
Industrial	31.3%	32.4%	30.9%
X^2	X^2=0.09, df=2, NS		
Naive	17.9%	27.6%	46.8%
Reasons	no reason shows basin, real equipment shows person washing eye best, self explanatory	no reason shows eye & water clearer, more descriptive better symbol	no reason clearer, more understandable eye & fountain clearest better eye

Figure 18. Fire safety equipment

Fire Extinguisher
A

Hose and Reel Connection
B

UNDERSTANDABILITY DATA		
Industrial		
C	96.5%	88.6%
C+P	98.8	95.4
X	1.2	1.1
N	0	3.4
Naive	N = 61	N = 54
C	95.1%	87.0%
C+P	96.7	92.6
X	3.3	5.6
N	0.0	1.8
Wrong Answers	fire hazard area	high pressure
	gas available here	
Confusions	*fire oxygen	

Figure 19. Fire alarm call point

A B C

UNDERSTANDABILITY DATA			
Industrial C C+P X N	N = 88 2.3% 10.2 59.1 13.6 fire alarm = 17%	N = 86 2.3% 4.6 37.2 8.1 fire alarm = 50%	N = 94 1.0% 6.3 1.1 0 fire alarm = 2.1% fire phone = 90.4%
X^2	X^2=100.59, df=2, p<.001		
Naive C C+P X N	N = 54 37.0% 48.1 48.1 0.0 fire alarm = 3.7%	N = 61 37.7% 42.6 39.3 6.6 fire alarm = 11.5%	N = 53 79.2% 79.2 9.4 0.0 fire alarm = 11.3%
Wrong Answers	noise area, hearing protection bells ringing school zone church signal, siren	high noise, use ear protection bell grinding wheel machine, rotating shaft fire caution vibration upon striking	
PREFERENCE DATA			
Industrial	12.6%	46.8%	34.2%
X^2	X^2=42.62, df=2, p<.001		
Naive	15.4%	43.6%	35.9%
Reasons	no reason shows bell	more understandable as an alarm no reason better, more easily recognized hammer & bell	no reason shows fire & phone indicates alarm location

Image B was selected as the most preferred image because it was more understandable as an alarm and could be more easily recognized. Reasons for selecting image C included that it showed a fire and phone as well as an alarm location while reasons for image A included that it showed a bell. Nevertheless, the message of fire alarm call point appears to be difficult to isolate symbolically from that of fire alarm sounder location.

5.2.5 Personal Protective Gear

The next category of symbolic referents to be considered is that of personal protective gear, figures 20 to 25. With the exception of images for respirator, almost every image tested well above the 85 percent criterion level. Four different graphic approaches were employed for the various referents: one piece of gear, two pieces of gear, gear on person, and putting gear on. Understandability was often greater for gear on person, although individual comparisons were generally not statistically significant. The preference data tended to favor the putting gear on approach, particularly for the naive participants. Despite the preference for this approach, it does not appear to be necessary to convey the message of "wear protective gear" since most symbols for protective gear tested above the 85 percent criterion. The simpler symbols, which can be more legible, appear to be sufficient to communicate the intended message.

Figure 20 presents data for "wear hard hat." There is a significant difference among the images with A, "putting on hard hat," performing most poorly. Confusions included ideas of hair protection, wear respirator, cover ears, hold onto hat, etc. Image C, hard hat alone, had the highest percentage of correct answers for both naive and industrial participants, and was significantly preferred by the latter group. (Naive people preferred image A, however.) Image C was selected because the image alone was considered sufficient, image B was chosen because it showed the hat on a person, and image A was preferred because it showed a person putting on a hat.

Figure 21 presents data for ear protection. Image C, ear protection on a person, received the highest percentage correct, but the difference in percentage correct between the three images was not significant. Image B, ear protection alone, tested below criterion level for industrial personnel. Industrial participants did better on all three images than naive because of the latter's tendency to define the images as (stereo) head sets rather than as protective gear. Again, familiarity with the industrial workplace tended to increase the understandability of this particular message. Answers related to noise hazard and head phones were identified separately for the industrial subjects although they are also included within the lenient category.

Both groups of participants expressed a strong and significant preference for image A, because it showed the gear being put on and had a greater detail. Images B and C were liked because they were simpler, clearer, and more visible. Image B of figure 31, presents data for a fourth graphic image which was not particularly effective for "hearing protection" but which was generally responded to as "noise hazard" or "noise hazard, wear ear protection." If the intention is to transmit information about a potential hazard, rather than the specific requirement for protective gear, this image appears to be a viable

Figure 20. Head protection required

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 86	N = 88	N = 94
C	84.8%	86.4%	88.3%
C+P	87.1	95.5	97.9
X	9.3	1.1	1.1
N	3.5	3.4	1.1
X^2	X^2=12.84, df=4, p<.05		
Naive	N = 61	N = 54	N = 53
C	80.3%	77.8%	96.2%
C+P	90.2	90.8	98.0
X	6.6	7.4	1.9
N	3.3	1.8	0.0
Wrong Answers	wear hair protection		
PREFERENCE DATA			
Industrial	29.5%	23.4%	46.6%
X^2	X^2=19.36, df=2, p<.001		
Naive	52.6%	19.2%	25.6%
Reasons	no reason shows putting hat on more graphic best, most understandable	no reason shows hat on person	no reason hat alone is sufficient clearest, most visible most recognizable, best

Figure 21. Ear protection required

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	79.8%	79.5%	79.1%
C+P	86.2	81.8	90.7
X	2.1	6.8	3.5
N	4.2	3.4	0
X^2	X^2=4.63, df=4, NS		
Naive	N = 53	N = 54	N = 61
C	45.3%	48.1%	45.9%
C+P	56.6	59.2	60.7
X	8.2	9.2	8.2
N	4.9	0.0	4.9
	headphones 26.2%	headphones 31.5%	headphones 26.2%
Wrong Answers	head phones 2.1% noise hazard 5.3%	tunnel noise hazard 7.9%	hearing test noise hazard 4.7% head phones 1.2%
PREFERENCE DATA			
Industrial	65.8	17.1	16.7
X^2	X^2=106.54, df=2, p<.001		
Naive	62.8	12.8	6.4
Reasons	no reason shows gear being put on more detail clearer, easier to understand	no reason simple, most visible	no reason simpler, clearer

Figure 22. Eye protection required

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 86	N = 94
C	81.8%	88.4%	84.0%
C+P	89.7	100	98.9
X	0	0	0
N	2.2	0	1.1
	glasses alone 7.97%		
X^2	X^2=1.50, df=2, NS		
Naive	N = 54	N = 61	N = 53
C	63.0%	78.7%	94.3%
C+P	87.1	91.8	98.1
X	12.9	8.2	1.9
N	0.0	0.0	0.0
Wrong Answers		none	
PREFERENCE DATA			
Industrial	10.6%	38.3%	50.7%
X^2	X^2=56.38, df=2, p<.001		
Naive	6.4	33.3	60.2
Reasons	no reason clearest, simplest	no reason person wearing glasses most meaningful	no reason goggles imply eye protection looks more like safety equipment clearer, more understandable

option (especially since 36 percent of the industrial personnel responded with "ear protection required" anyway).

Figure 22 presents data for eye protection. Using lenient scoring criteria, all images tested above criterion level with no significant difference between images emerging, although image A, glasses alone, had the lowest percentage of correct responses. This was due to some participants merely indicating "wear glasses", not "wear safety glasses". Image C, goggles, was preferred because it appeared to indicate a greater level of protection. Image B was preferred because it showed the intended action, and had greater meaning, while A was believed to be clearest. Although all the images were tested as general eye protection equipment, the good performance of image C for all participants indicates that if a separate image is needed for goggles, as opposed to glasses, this image could effectively serve that need. Image B appears effective for the general protection, since it elicited no wrong answers at all from industrial personnel.

Figure 23 presents data for hand protection. No significant understandability differences among images emerge, although image B elicits a number of confusions related to "stop", particularly from naive participants. All images except image B exceeded the criterion level with lenient scoring for all people. Image A, "putting on gloves", was preferred by both sets of participants because it showed this action. Reasons for selecting image B include that it was simpler and for image C that it shows two hands.

Figure 24 presents data for foot protection. There is a significant difference between images, with image A having the highest percentage correct and image C the lowest for industrial personnel. Differences between lenient and strict scoring criteria are attributable to failure to indicate that safety shoes or boots are required. Image C also elicited a large number of answers (12 percent) related to wearing rubber boots rather than to safety footgear. Nevertheless, image C was preferred because it showed the boot being put on the person. Reasons for preferring image A included that it showed the hard toe, and for image B, that it was simpler.

Figure 25 presents data for three images for respirator required. Differences in scoring criteria are responsible for the variations in percentages correct and partially correct. Only about half the participants strictly identified any image as meaning "respirator required". If ideas such as noxious fumes and face or breathing protection are considered partially correct, this increases leniently scored performance for all three images. If "gas mask required" is also included, this further increases the percentage of correct definitions for images A and C for both groups to 90 percent or better. The words "gas mask" may refer to the kind of equipment issued during World War I to supply air during a gas attack, rather than the modern day respirator; hence this answer is categorized separately for industrial participants. If this answer is scored as leniently correct, then the performance of symbols A and C exceeded the criterion level and was significantly different from image B. Image B was not well understood by any scoring criterion and elicits numerous confusions related to scuba gear and electronic equipment. Participants expressed a significant preference for image A, although this preference was somewhat less marked for naive

Figure 23. Hand protection required

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	86.2%	84.9%	82.9%
C+P	96.8	90.7	90.8
X	3.2	5.8	5.7
N	0	3.5	3.4
X^2	X^2=4.42, df=4, NS		
Naive	N = 53	N = 61	N = 54
C	90.6%	60.7%	87.0%
C+P	100	64.0	100
X	0	31.2	0
N	0	3.3	0
Wrong Answers		stop direction follow left turn	wash your hands watch fingers, handle with care
PREFERENCE DATA			
Industrial	65.8%	17.1%	16.7%
X^2	X^2=228.19, df=2, p<.001		
Naive	89.7%	5.1%	5.1%
Reasons	no reason shows action better, clearer, easier to understand	no reason simpler, clearer	no reason shows two hands

Figure 24. Foot protection required

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 94	N = 86
C	82.9%	70.2%	57.0%
C+P	96.5	95.7	84.9
X	1.1	4.2	13.9
N	2.3	0	1.2
X^2	X^2=18.76, df=4, p<.001		
Naive	N = 54	N = 53	N = 61
C	53.7%	62.3%	50.8%
C+P	79.6	90.6	90.2
X	16.7	9.4	8.2
N	3.7	0.0	1.6
Critical Confusion	*leave shoes here		rubber boots needed 12.8%
PREFERENCE DATA			
Industrial	14.4%	22.5%	60.8%
X^2	X^2=83.68, df=2, p<.001		
Naive	1.3	14.1	84.6
Reasons	no reason shows hard toe, looks like safety shoes easiest to understand	no reason simpler, easier to read	no reason action of putting on boot most meaningful boot & person

Figure 25. Respiratory protection required

A

B

C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 86	N = 94
C	51.1%	51.2%	44.7%
C+P	73.2	67.5	66.0
X	2.3	8.1	1.1
N	2.3	18.6	3.2
	gas mask = 21.6%	gas mask = 5.8%	gas mask = 24.5%
X^2	X^2=0.37, df=2, NS		
Naive	N = 54	N = 61	N = 53
C	83.3%	50.8%	77.4%
C+P	92.5	60.6	94.4
X	1.8	24.6	0.0
N	0.0	11.5	0.0
	gas mask = 5.6%	gas mask = 3.3%	gas mask = 5.6%
Wrong Answers		scuba gear, diving electronic gear, robots	
PREFERENCE DATA			
Industrial	61.9%	9.2%	27.5%
X^2	X^2=96.72, df=2, p<.001		
Naive	50.0%	16.7%	26.9%
Reasons	no reason detail of mask person & mask clearer, easier to understand best	looks more like respirator no reason	no reason good mask more easily understood

subjects. Image A is a more realistic representation of a person wearing a mask than the more stylized image C. Unfortunately, the respirator shown in image A is out of date and should be modernized. It was preferred, however, because it showed the most detail and was shown on a person. Image B was believed to look like a respirator while image C was believed to be a good representation of a mask. Image A of figure 31 presents data for an ISO proposed symbol for dust mask, similar to but distinct from the idea of respirator.

When leniently scored as dust mask, this image came close to the 85 percent criterion level, with no critical confusions. Naive participants appeared to have even fewer problems with this image, perhaps because it resembles dust masks commonly sold for home use.

As noted earlier, at least one image for all the personal protective gear referents was understood at or above the criterion level, if a lenient scoring criterion is adopted. Distinguishing between images on the basis of the understandability data is almost impossible, and on this ground alone, it appears that almost any image could be selected. However, because of the legibility problems inherent in the greater detail associated with the "putting on gear" approach, and because the gear alone approach is typically the least well understood, if a consistent set of images is desired, portrayal of gear on a person appears to be an effective general approach. Symbols using this approach had slightly higher percentages correct for four of the six referents studied.

The use of color and background shape for protective gear symbols was only infrequently addressed by any of the participants in the preference portion. Only two images, goggles and breathing apparatus, were presented in yellow; all other images were blue, and presented in a circular surround. Five people commented that these latter images should have been presented on a yellow triangle. For goggles, however, ten percent of those prefering this image preferred it because it was in the colors of hazard or caution signs. No participant, however, commented upon the use of blue or the round surround shape. It does appear, however, that some industrial personnel recognize the international coding system which uses the triangle to indicate the presence of a hazard and yellow to indicate caution.

5.2.6 Egress-related Referents

The next category to be considered is that of egress related referents. Three images each were studied in the main experiment for emergency exit (figure 26) and general exit (figure 27). Lerner and Collins (1980) and Collins and Pierman (1979) called attention to the need to develop an effective emergency exit symbol, as well as to the generally poor performance of currently proposed exit symbols. Data obtained in the present experiment for emergency exit for symbols B and C of Figure 26 generally replicate those of Lerner and Collins. Symbols A and C are correctly identified by most industrial personnel. Industrial participants, however, did more poorly on symbol B (strict criterion) in the present experiment, with a large number of responses related to "do not run". Symbols A and B also received several critical confusions related to "enter" and "do not open door during fire". Only symbol A performed above the criterion level for lenient scoring for both groups of participants. Emergency

Figure 26. Emergency exit

	A	B	C
UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 88	N = 86
C	90.4%	64.8%	90.7%
C+P	95.7	72.7	93.0
X	4.2	21.6	4.7
N	0	5.7	2.3
X^2	X^2=26.75, df=4, p<.001		
Naive	N = 53	N = 54	N = 61
C	83.0%	68.5%	82.0%
C+P	88.7	83.3	82.0
X	11.3	14.8	18.0
N	0.0	0.0	0.0
		passageway 1.8	
Wrong Answers Critical Conclusions	fire, run beware, fire *do not open door if fire 1%	do not run 18% *enter 1%	fire hazard area run, keep away from fire
PREFERENCE DATA			
Industrial	53.2%	21.6%	23.9%
X^2	X^2=42.62, df=2, p<.001		
Naive	51.3%	19.2%	19.2%
Reasons	no reason better characterized red implies emergency shows both emergency & egress more meaningful	no reason green shows go safety others restricted to fire exit	no reason shows emergency & direction

exit is a concept intended for general public use; these data suggest that such a message which is initially understandable (without training) continues to be difficult to symbolize.

Participants expressed a general preference for symbol A claiming that it was better characterized, the color red implied emergency, it showed both emergency and egress, and was more meaningful. Image B was selected because green indicated both go and safety and the other symbols appeared to be restricted to fire exit. Image C was chosen because it showed both emergency and direction.

Image C of figure 31 presents an additional emergency exit symbol showing a man running plus a door and an arrow. The percentage of correct responses to this image is lower by 20 to 25 percent than to the same image with a figure walking (image C of figure 27) due to numerous answers related to "do not run" (13.5 percent) and men's room (5.8 percent). These confusions were not elicited by the image with the man walking to the door. It is interesting to note that a relatively simple shift in figure rendition decreased the number of correct answers noticeably.

Figure 27 presents data for general exit. Only image C reached the 85 percent criterion level for lenient scoring for both groups. Image B, proposed by DoT, (AIGA, 1979) received a very small percentage of correct answers regardless of scoring criterion or participant group studied. Image A received only 40 to 60 percent of correct answers for industrial personnel. Furthermore, all images, particularly image B, received a large number of opposite responses. For image A, two percent of those tested responded with "enter" (as opposed to "exit"), for image B, twelve percent of those tested responded with "do not exit, enter" and "do not cross or start", while for image C, one percent responded with "dead end." Image B appears to be singularly unsuccessful in that it was not understood and elicited a large number of opposite responses.

Participants expressed an overwhelming preference for image C because it showed figure, direction, and door, and was less confusing than the others. Image C is the least abstract of the images tested and the most frequently correctly identified. It may not, however, be an effective exit message when located directly over a door, as are current "EXIT" signs (AIGA, 1979). No reasons were given for preferring B, while A was preferred because the arrow pointed to the opening.

Consideration of the various images proposed for exit and emergency exit suggest that those showing a figure, flames, door or an arrow received the greatest percentage of correct answers. The images that were successful in terms of percentage correct are all complicated visually, involving several graphic elements. Yet these complicated images may be less likely to be detectable or legible in smoke. Selection of a successful exit symbol is contingent upon satisfying both comprehension and legibility criteria. It does not appear than an image which satisfies both needs has yet been located and evaluated. Furthermore, the criterion for successful comprehension should perhaps be set higher than 85 percent correct definition due to the criticality of the message.

Figure 27. Exit

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 86	N = 94
C	39.8%	2.3%	82.9%
C+P	59.1	26.7	90.3
X	37.5	39.5	3.2
N	3.4	33.7	3.2
			passageway = 3.2%
X^2	X^2=160.69, df=4, p<.001		
Naive	N = 54	N = 61	N = 53
C	68.5%	1.6%	79.2%
C+P	83.3	6.6%	86.7
X	13.0	81.5%	5.7
N	3.7	24.1%	1.9
		passageway = 3.7%	passageway = 5.7%
Wrong Answers	one way only narrow passageway aisle, walkway, thruway	roadway, highway divided building, decision civil defense, safe shelter proceed, cross with caution go straight	
Critical Confusion	*enter 2%	*don't exit, enter 8.1% *don't cross, pass, start 4.6%	*dead end 1.1%
PREFERENCE DATA			
Industrial	12.8%	2.3%	78.2%
X^2	X^2=241.4, df=2, p<.001		
Naive	9.0%	1.3%	80.8%
Reasons	no reason arrow points to opening	no reason	no reason figure & direction shows door & way out better, others confusing more meaningful all bad

Figure 28. No exit

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 94	N = 86	N = 88
C	13.8%	27.9%	34.1%
C+P	18.0	38.4	59.1
X	45.7	31.4	1.1
N	14.9	3.5	2.3
	no entry 21.3%	no entry 26.7%	no entry 37.5%
X^2	X^2=35.87, df=4, p<.001		
Naive	N = 53	N = 61	N = 54
C	11.3%	37.7%	26.6%
C+P	17.0	39.3	35.2
X	83.0	41.0	55.6
N	0.0	0.0	1.8
		no entry 19.7%	no entry 7.4%
Wrong Answers	fire door shut, close door prison, jail secure, protected area	no running slippery, tripping hazard no loafing, standing danger crossing, do not cross	
Critical Confusion	*keep door/area locked 14.9% *emergency exit 2% *entrance 2%	*exit, exit slowly, open doorway - 3.4%	
PREFERENCE DATA			
Industrial	4.3%	30.0%	64.9%
X^2	X^2=124.3, df=2, p<.001		
Naive	1.3%	39.7%	57.7%
Reasons	door locked, no way out no reason	no reason universal slash for no more meaningful, stands out more similar to highway "no entry"	no reason X for no more meaningful figure passing by door better, door best simpler, less cluttered

Figures 28 and 29 deal with symbols for no exit and no entrance, respectively. When Collins and Pierman (1979) and Lerner and Collins (1980) examined several symbols proposed for "no exit", they found that no symbol tested was effective and several had serious critical confusions. In the present experiment, figure 28 reveals that again, no image regardless of scoring criterion or participant group, received a high percentage of correct answers. Furthermore, all of the images received as large a percentage of incorrect answers related to "no entry" as they did fully correct answers for "no exit", indicating that the message of "no way out" was not successfully communicated. Images A and B also received between two and three percent responses related to exit or entrance, a critical confusion. Furthermore, 15 percent of the answers to image A indicated that it meant to keep door locked. Image C was correctly identified by the largest percentage of subjects but fell short of the 85 percent criterion level. It was, however, the most frequently chosen image in the preference data because of the prohibitory "X", the figure passing by the door, and its simplicity. Image B was selected because of the prohibitory slash and because it appeared more meaningful. Image A was selected because it showed the door being locked. These data reinforce the difficulty seen in previously reported data (Lerner and Collins 1980; Collins and Pierman, 1979) of determining a symbolic image which successfully communicates the message of "no exit" or "no way out".

Figure 29 presents data for three images specifically intended for "no entry" or " no admittance". Despite extensive use on the highways, image A is not understood to mean "no entry", at least for an industrial setting. In fact, responses from naive participants indicated a greater comprehension of this image, although fewer than half of these participants interpreted it correctly. Furthermore, image A elicited answers related to hallway or passageway from almost six percent of those tested. As ISO TC 145 has recently recommended (Zwaga, 1981), this symbol might best be restricted to vehicular "no entry". Although image B does not communicate the strict message of "no entry" well at all, it does communicate the idea of "stop" to 72 percent of those tested (industrial or naive). Image C indicates "no entry" to about 75 percent of those tested and "no standing" to another 12 percent. Image C was also the most preferred image by industrial personnel, as it indicated people not allowed and possessed the prohibition slash. Image B was preferred because it was easier to identify with and contained a hand signal. Image A was recognized as a common symbol, even if it was not correctly identified.

Data presented in figures 26-29 for egress-related referents indicate that these ideas continue to be difficult to symbolize effectively. Egress symbols which may be most legible may not be well understood and vice versa, while ideas related to prohibited exit and entry are not well understood regardless of legibility. The poor performance of symbol A for no entry (an abstract symbol) suggests that it does not appear to have achieved universal comprehension despite widespread use on highways.

A final egress related referent, "use stairs, not elevator in fire" is presented in figure 30. Images A and B both received at least 85 percent correct responses for all participants for lenient scoring. Differences between strict and lenient scoring were due to answers related to fire exit, fire escape or fire stairs which did not include both the message "use stairs" and "do not

Figure 29. No entry

A B C

UNDERSTANDABILITY DATA			
Industrial	N = 88	N = 86	N = 94
C	20.4%	13.8%	74.4%
C+P	30.6	85.0	76.7
X	30.7	12.8	7.9
N	38.6	2.1	4.7
			no standing 11.6%
X^2	X^2=178.69, df=4, p<.001		
Naive	N = 54	N = 53	N = 61
C	35.2%	24.5%	63.9%
C+P	48.2	92.4	78.7
X	42.6	7.5	19.7
N	9.2	0.0	1.6
Wrong Answers	bright light, red light beware, caution, danger low ceiling red dot	quiet, no noise wear hand & ear protection slow down	do not cross no running, loitering
Critical Confusions	*hallway, passageway 5.7% no way out, dead end 2%		*safety walkway 1%
PREFERENCE DATA			
Industrial	8.3%	38.3%	47.1%
X^2	X^2=58.65, df=2, p<.001		
Naive	11.5%	38.5%	33.3%
Reasons	common symbol no reason	no reason easier to identify with better, more understandable hand signal	no reason indicates people not allowed more understandable like traffic sign slash for no

Figure 30. Use stairs in case of fire, not elevator

A B

UNDERSTANDABILITY DATA		
Industrial	N = 94	N = 88
C	22.3%	62.5%
C+P	90.4	86.4
X	8.51	12.5
N	1.06	1.14
X^2	Z=32.24, df=2, p<.001	
Naive	N = 53	N = 54
C	75.5	81.5
C+P	88.7	90.7
X	11.3	7.4
N	0.0	1.9
Wrong Answers	get out, leave watch out for fires, danger do not run down stairway in fire	fire exit, blocked do not enter
PREFERENCE DATA		
Industrial	21.2%	77.0%
X^2	Z = 8.40, p<.001	
Naive	7.7%	87.2%
Reasons	no reason more understandable clearer, easier to spot at a glance	no reason indicates don't use elevator more meaningful shows both meanings better

Figure 31

	Dust Mask A	Noise Hazard B	Emergency Exit C
UNDERSTANDABILITY DATA			
Industrial	N = 86	N = 84	N = 52
C	67.4	36.2	61.5
C+P	84.8%	90.3	67.3
X	15.1	8.5	23.1
N	12.8	2.1	9.6
Naive	N = 53	N = 53	N = 54
C	78.7	9.4	68.5
C+P	96.8	94.3	92.6
X	0.0	5.7	3.7
N	0.0	0.0	3.7
	gas mask 5.79		
Wrong Answers	sand blasting area painting or spraying	listen audio alarm, bell ring sound, radio waves	do not run restrooms *no exit, obstacle in way 3.8%
Critical Confusions			

use elevator". Image A does not, in fact, contain any imagery related to the elevator concept--hence the large difference between strict and lenient scoring for industrial personnel. (Answers generally related to exit were typically scored as correct in the pilot but were only scored as partially correct in the main experiment). Participants expressed a strong preference for image B because it depicted both meanings, including the elevator. Again, image B may suffer greater legibility problems under smoke or dusty conditions. This referent, furthermore, appears less critical for industrial sites where egress is normally by stairs.

Data contained in figure 31 have already been discussed under the individual referents of respirator, ear protection, and emergency exit.

6. CONCLUSIONS

6.1 SELECTION OF A PRELIMINARY SYMBOL SET BASED UPON UNDERSTANDABILITY DATA

The data on symbol understandability obtained in the present experiment were used to select a preliminary set of symbol images which appear to convey the various referents effectively. The selection is based upon a set of arbitrary decision rules, given below. Before describing these rules, however, certain intrinsic limitations to the generalizability of these conclusions must be addressed.

Throughout the present report, understandability has been emphasized as a major consideration in symbol evaluation. While the understandability of a set of symbols should be a primary consideration, there are other important factors which should also be addressed, particularly when several symbols for the same referent appear about equally understandable. Consideration of all the factors which determine the selection of the best, most effective set of symbols was beyond the scope of this report. As a result, the symbols selected must not be viewed as a set of final recommendations.

Some of the factors which should be addressed in the final design of a set of industrial safety symbols are: legibility, under both normal and degraded viewing conditions; conspicuity (ability to attract attention); behavioral effects as well as accident reduction (field studies); confusability (of the symbols within a set); reproducibility; cost; and susceptibility to vandalism. In addition, the set should reflect a consistent graphic style both for the interior image and the background shape. Both the AIGA (1979) and Follis and Hammer (1979) have emphasized the need for an integrated, internally consistent graphic style. Needless to say, the symbols selected as effective representations of the various referents were drawn from a variety of sources and need to be adapted to a consistent graphic style. Based upon these considerations, the symbols presented here must be viewed as a preliminary selection which requires further refinement. The symbols selected can, however, serve as a reasonable basis for the further development of a set of effective industrial safety symbols.

With all the above reservations in mind, the set of decision rules can now be discussed. These rules were utilized to select the interior graphic image for each referent. An additional research project on effective background (surround) shape (now in progress) will provide criteria for selecting surround shapes for these images.

Although the criteria are necessarily somewhat arbitrary, they represent a reasonable basis for decision. The minimum criterion for a symbol to be selected was that it meet the ISO recomendation for understandability. This means at least 85 percent correct definitions and no more than five percent critical confusions for a given symbol. If no symbol for a referent met these minimum specifications, no suggested image is given. Leniently scored data were used as the basis for symbol selection; of course, use of the more stringent scoring criterion would result in the exclusion of more symbols.

If more than one symbol for a referent met the ISO recommendations, then the more frequently understood image was selected. However, a minimum difference between symbols was required to avoid basing this choice on spurious differences. A minimum difference of six percent was required, since this corresponded to approximately plus or minus two standard errors of the mean, or an approximate 95 percent confidence interval.[1]

If two or more candidate symbols still could not be discriminated, the next decision rule involved correspondence with existing symbol standards. Conformance with existing symbol standards appears to be a worthwhile goal, if the symbol has met the understandability criteria outlined above. The three most relevant standards are the DoT (1979) set, the ISO draft international standard (DIS 3864.3), and the Treasury board of Canada Federal Identity Program (1980). Since the DoT symbols are finding widespread adoption in the United States, and appear to be the model for graphic features of a number of additional symbol sets (FMC, 1978), weight is given to these particular recommendations where the standards disagree among themselves.

Finally, if the previous criteria could not identify a single image for a referent, the preference data from the present experiment were utilized. The preference data are useful in that the procedure allowed subjects to choose whatever criteria seemed important to them. At the same time, it must be recognized that these criteria may not always be the most appropriate. Further, the inability of many subjects to give a reason for their preference choice suggests that their opinions may not have been strong or meaningful. For these reasons the preference data are considered only as supplementary to the understandability findings. In actual fact, this final decision rule was seldom involved (see table 6).

Table 6 lists the referent messages, the suggested symbol, if any, for each referent, and the decision criteria by which the symbol was selected. Figure 32 illustrates the selected symbols. This selection is made in the interest of differentiating and capsulizing the performance of the wide variety of symbols studied. Beginning with the initially collected catalogue of symbols (section 3.3), several hundred images were subjected to some form of evaluation. While it is emphasized that limitations exist in the scope of the workplace sample and the number of factors considered, the final selections are nonetheless useful as examples of successfully understood symbols and as potential items to be included in the development of a refined and consistent set of industrial safety symbols.

6.2 GENERAL CONCLUSIONS

A number of conclusions can be drawn about the data and information reported in the previous sections. These center around five major issues which include the

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[1] The standard error for the percentage correct measure can be estimated by using binomial approximation to the normal curve. Based upon this relationship, the standard error of the proportion of items correct is estimated by $\sqrt{NPQ}/N$ (where N is the number of subjects per group, P is the proportion of correct answers, and Q is the proportion of incorrect answers).

Table 6

Symbols Selected to Represent each Referent***

REFERENT	SYMBOL	SELECTION BASIS
Electrical	C	Only symbol to reach criterion level
Explosion	B	Reached criterion: 6% greater than C
Flammable	-	No symbol reached criterion
Corrosion	A	Reached criterion
Poison	-	No symbol reached criterion
Entanglement	C	Reached criterion
Slip	C	All reached criterion; no 6% difference: C in Canadian standard and is preference choice
Trip/Fall	A/C	Both reach criterion; two messages intended
Overhead	C	Reached criterion (referent problem exists--see text)
General Warning	-	Does not reach criterion
Radiation	-	Does not reach criterion
Laser	-	Does not reach criterion
Biohazard	-	Does not reach criterion
No Smoking	B	Both reach criterion: B recommended by DoT: B is preference choice
No Open Flame	B	All reach criterion: B consistent with DoT graphic approach for No Smoking: B is preference
First Aid	A	Both reach criterion; A is Canadian, ISO standard: A is preference choice
Safety Shower	B	Reached criterion (legibility problems may exist)

***These choices are preliminary, based upon the specific results from a limited population of industrial employees, and should NOT be taken as a final recommen- of a complete set of industrial safety symbols.

Table 6 Continued

Symbols Selected to Represent each Referent***

Eyewash	-	No symbol reached criterion
Fire Extinguisher	same	Reached criterion
Hose & Reel	same	Reached criterion
Fire Alarm	-	None reached criterion (referent problem exists)
Head Protection	B	All reach criterion: C & B 6% above A: B is Can/ISO standard: C is preference choice: recommend redesign of B in line with Canadian approach
Ear Protection	C	A & C reached criterion: no 6% difference C is ISO/Can Standard: A is preference choice: recommend redesign of C in line with Canadian standard
Eye Protection	B	All reached criterion: B & C 6% greater than A, B is ISO/Can standard: C is preference choice: recommend redesign of B in line with Canadian standard
Hand Protection	A	All reach criterion: A 6% greater than B or C
Foot Protection	A	All reach criterion: A & B 6% greater than C: A is ISO standard: C is preference choice: recommend redesign of A in line with Canadian standard
Respiratory Protection	-	No symbol reached criterion, unless "gas mask" answers are included with leniently scored data for A: recommend redesign
Emergency Exit	A*	A & C reach criterion: no 6% difference: B is proposed ISO standard: A is preference choice

*See text p. 77 for a discussion of problems relating to the graphic elements inherent in the exit symbol imagery. Further research is in progress on the legibility of exit symbol indications.

Table 6 Continued

Symbols Selected to Represent each Referent***

Exit	C*	Reached criterion level
No Exit	-	No symbol reached criterion level
No Entry	B	B barely reaches criterion level due to large number of answers related to "stop" or "halt"
Use Stairs in Fire	B	Both reach criterion level: no 6% difference: no standard exists: B is preference choice
Forklift Truck	A	A & C reach criterion: no 6% difference: A is in ISO standard: A is preference

***These choices are preliminary, based upon the specific results from a limited population of industrial employees, and should NOT be taken as a final recommendation of a complete set of industrial safety symbols

*See text p. 77 for a discussion of problems relating to the graphic elements inherent in the exit symbol imagery. Further research is in progress on the legibility of exit symbol indications.

Figure 32

Symbols Selected to Represent each Referent**

ELECTRICAL

C

EXPLOSION

B

FLAMMABLE

CORROSION

A

POISON

ENTANGLEMENT

C

SLIP

C

TRIP/FALL

A

C

OVERHEAD

C

**These choices are preliminary, beased upon the specific responses of a limited population of industrial personnel, and should NOT be taken as the final recommendation of a complete set of industrial safety symbols. Futher research is in progress.

Figure 32 Continued

Symbols Selected to Represent each Referent

GENERAL WARNING

RADIATION

LASER

BIOHAZARD

NO OPEN FLAME

B

NO SMOKING

B

FIRST AID

A

SAFETY SHOWER

B

EYEWASH

Figure 32 Continued

Symbols Selected to Represent each Referent

FIRE EXTINGUISHER

HOSE AND REEL

FIRE ALARM

HEAD PROTECTION

B

EAR PROTECTION

C

EYE PROTECTION

B

FOOT PROTECTION

A

RESPIRATORY PROTECTION

HAND PROTECTION

A

Figure 32 Continued

Symbols Selected to Represent each Referent

EMERGENCY EXIT

A

EXIT

C

NO EXIT

NO ENTRY

B

USE STAIRS IN CASE OF FIRE, NOT ELEVATOR

B

FORK LIFT TRUCK

A

understandability of the symbols tested and the appropriateness of the referents and symbols tested; procedural and methodological concerns; scoring criteria; reliance upon training; and need for further research on industrial safety symbols.

The first and foremost issue is that of the understandability of the individual symbols tested. For most of the referents studied, at least one image was reasonably well understood. Exceptions to this include symbols for radiation, laser, biohazard, general warning, combustible, eyewash, exit, no exit, no entrance, and fire alarm call point. The first four referents are characterized by very low percentages of correct responses and high degrees of graphic abstraction. Data obtained in the present experiment suggest that highly abstract symbols are not particularly well understood. Messages related to hazard warning and egress generally appear to be more difficult to communicate effectively than those for protective gear perhaps because of the highly pictorial and directly representative nature of the graphic images studied for the latter.

If a general conclusion could be drawn about the kind of graphic image which communicates its message effectively upon initial viewing, it would be that pictorial, representational messages often involving a person and the hazard, action, or piece of gear appear to be most effective. Certainly, the very abstract images studied in this experiment were generally not identified correctly, often despite long use. (The cross for first aid is an exception, and even this was correctly identified by only about 90 percent of the subjects.) On the other hand, the more representational images were generally identified correctly and often preferred. Inclusion of a person or part of a person so that the consequences are depicted, such as showing the hand in a set of gears or the hard hat on the head, appears to be an effective approach. These general conclusions, of course, are inferences drawn from performance on specific symbols, and as such are necessarily tentative. Nevertheless, a number of specific symbols emerged as effectively communicating their intended meaning. Correct definition of a symbol does not necessarily imply, however, that correct behavior will follow. The effectiveness of symbol and word signs in eliciting and maintaining safe behavior is a fertile topic for further research.

The data obtained in the present study also indicate that of the 33 referents tested, only two seemed ineffective or inappropriate for industrial applications. These are "fire alarm call point" and "use stairs, not elevators in case of fire". The former suffers from confusion over whether the intended meaning is to designate the location of a place where an alarm is turned in or is to indicate the alarm location itself, as well as whether the purpose of the alarm is to warn building inhabitants or to notify the fire department. Greater precision in defining the intended meaning is needed for these various concepts before an effective symbol can be developed. The other message which concerns the use of stairs, rather than elevators during a fire would be applicable only to those industrial sites which possess elevators. Symbols for two other referents, "overhead hazard" and "fall", appeared to convey at least two messages -- "machinery in operation overhead" and "falling objects likely" with "wear hard hat" as a possible third message. "Fall" can be separated into two messages, "trip-over an object" and "fall from elevation."

The potential refinement in referents points to a philosophical problem with symbols. If one accepts the premise that more representative symbols communicate more effectively, how specific or representative should the resulting image be? It is obviously more efficient to use a generic image to indicate a class of message than to use a specific image to indicate each member of this class. The generic approach is clearly the one taken by the various international standards. For example, a "circle, slash and cigarette" means "no smoking" of anything, even though pipes and cigars are not depicted. A "head with glasses" means "wear eye protection" leaving the kind of protective device up to the user, although instances may exist for which a more specific symbol, such as "wear goggles", is desirable. Determining the effectiveness of every proposed message and symbol combination was clearly an impossible task for this study. Instead, the messages that appeared to be most critical from the sources given in section 3 were studied in the hope that this information, albeit limited, would prove useful to those concerned with industrial symbols. The use of many, specific images depicting a set of limited messages may potentially confuse the user, who is forced to distinguish between very similar images. The end concern must always be for the users and the effectiveness of the message in communicating with them.

Another issue that emerged in the course of the present study is that of methodological procedures. The experimental approach followed for this report, is in some ways a "worst case" situation. Although the instructions indicated that the symbols were all related to industrial hazards and safety, no specific context was provided for the individual symbols. There were several reasons for this procedure. First, since context may provide additional information, testing the symbol by itself is a conservative, or "worst case" procedure. Secondly, as discussed in section 3.2, it may not be possible to find a single context that is representative for a symbol, especially across factories and industries. A context unfamiliar to a worker or inappropriate to his industry could even interfere with communication. Finally, in actual usage, an observer might simply not be attentive to the context in a given encounter with a sign. This is especially important given the relatively high injury rate for new workers. Issues related to context and familiarity remain important, and can be seen in the somewhat poorer performance of the naive participants on workplace specific messages such as eyewash and ear protection.

Other considerations that emerged as a result of the experimental procedure are related to scoring concerns. Although the use of a definition procedure is one of the best ways to obtain confusions and inappropriate responses, it is sometimes difficult to determine what a subject meant by a particular answer. As an example, for the ear protection symbols, "wear headphones" was a frequent answer. Did the subjects mean "wear communication headsets," or "stereo headsets" or did they simply not know the correct term for ear protection? Similarly, for "combustible", answers emerged which were related to the presence, rather than the likelihood, of fire. It is unlikely that subjects really expect these fire symbols to be stored away, only to be put up in the case of a fire. Yet, their answers do not indicate an awareness of the idea that "something might catch on fire". These scoring problems might not be elicited with a different procedure--but the confusions also might not emerge.

Another issue related to scoring difficulties concerns the problems that some participants had with simply writing down definitions. At least one site studied contained a large number of people who were not at all skilled at written tasks, although they were technically literate. Although they may have understood the symbol, they had great trouble expressing themselves so that the raters could decipher their intent. Problems of poor handwriting and verbal incoherence abounded. In addition, decisions about subtle distinctions required during scoring can lead to substantial differences between scorers, or even for the same rater at two different times. The procedure described in section 4.3.7 was designed to minimize inconsistancies. In some cases, review of the pilot study protocols led to slightly revised scoring criteria for the main experiment, which produced clear differences in results. In addition to the difficulties involved in scoring the responses, the volume of data obtained was somewhat overwhelming and requied considerable time commitment. Use of a multiple choice procedure using confidence ratings could avoid some of these problems (Lerner and Collins, 1980).

An unanticipated finding from the present experiment was the relatively poor performance of several symbols that have been widely used for some years and with which industrial personnel might reasonably be expected to be familiar. These include the DoT/UN symbols for flammable, electricity, poison, and radiation, as well as the DoT symbol for no entry. Each of these symbols was identified correctly by fewer than 75 percent of the industrial personnel tested. Yet, these symbols are widely used on industrial containers and trucks, so that they should have been somewhat familiar. The difficulty of teaching the meaning of abstract symbols is underscored by the poor performance of the radiation and the DoT "no entry" symbols. Long use of these symbols has not led to good comprehension as measured by the experimental procedures used in this report. The relatively poor performance of these symbols suggests the need to evaluate symbol performance, in terms of understandability, before adoption of a symbol standard. It also suggests that informal training through the simultaneous presentation of a symbol with a word label may not be particularly effective, at least for these symbols. The issue of training remains largely unresolved. For example, Griffith and Actkinson (1978) found that varying the type of training method did not appear to improve performance for the highway symbols that they tested. As a result, it is of critical importance to determine the initial understandability of any symbols designed to warn of industrial hazards or to provide safety information. Furthermore, if a training program is employed, it could focus on teaching safe performance, using the symbols as reinforcement and increasing already good comprehension, rather than "teaching" obscure or unfamiliar imagery.

Throughout the preceding paragraphs, understandability has been treated as though it were a clearly defined entity. Because it is not, a criterion of 85 percent correct responses was set as a tentative cut-off value below which a symbol could be said not to communicate. Similarly 5 percent critical confusions was also suggested as a cut off to eliminate those symbols for which substantial misconception and inversion exist. These values were adopted from standards groups and previous studies; although they appear reasonable, the criteria are by necessity arbitrary and subject to discussion. For example,

adoption of more lenient or stringent criteria is certainly possible. Conceivably, the level of hazard or potential danger to the user could be used as an index by which to set a criterion. Symbols for more dangerous situations could require a higher percentage correct, for example, before they are used as the sole hazard-warning message. More lenient criteria could be selected if training were provided, or additional verbal material added, or if workers were familiarized with the symbols and the intended hazards. Selection of an acceptable criterion cut-off appears to depend on the criticality of the message, as well as on opportunities for training or providing additional verbal material.

This study systematically identified those workplace messages which require a standard symbol image and then attempted to select the most suitable image from a set of candidates for each referent. The results of the experiment suggest some general findings, but a number of questions remain unanswered relating to the effectiveness of industrial safety symbols. Data presented in this report represent the responses of a limited set of industrial and non-industrial personnel. As such, they provide an indication of, but not the final assessment of workplace safety symbol effectiveness. A number of general research questions also remain to be addressed. First, the effectiveness of both symbol surround shape and color in encoding hazard and safety information must be addressed. While these did not appear to have a great impact upon the percentage of correct answers to a symbolic image, subjects' comments indicated an awareness of some coding elements; specifically, yellow for caution, red for danger, fire and red cross, triangle for hazard warnings, and circle and slash for prohibition. In regard to the triangle, the question arises as to whether this shape conveys enough information about the presence of a hazard to offset its reduction of the area occupied by the image. Would another shape such as a diamond or octagon convey the same type of hazard warning? Such a question can only be answered by a combination of laboratory visibility research and field research on perceived hazardousness. Secondly, images eliciting a high percentage of correct answers should be studied further to determine their detectability and discriminability under reduced visibility conditions. Many of the signs surveyed during the site visits were often dusty and partially obscured. Selection of the most legible symbol to allow maximum opportunity for detection would appear appropriate, when combined with data on symbol comprehension. A third area for further research involves a comparison of the effectiveness of word and symbol signs in achieving the desired safe behavior. Which signing approach, word only or symbol only, is more effective, or is a combination of both, the most effective?

Finally, there is a great need to develop a consistent set of safety symbols, designed according to consistent graphic principles such as those suggesed by the AIGA (1974) and evaluated according to both field and laboratory procedures. The data reported in this report provide a good indication of the messages required as well as an initial assessment of several symbols for each of these messages. The final set of symbols should then be assessed with industrial personnel to determine overall understability and in a laboratory to evaluate visibility. In this way, the most effective set of symbols for hazard warnings and safety messages can be used, to increase the safety of those in the industrial workplace.

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Appendix A

Details of Experimental Procedure Including Instructions to Instructions to the Participants

Appendix A presents the three orders of symbol images, giving the symbol number arbitrarily assigned by the experimenters, the intended referent, and the image content. The order of presentation of the symbols within each group was randomized for each group of participants. Each group of participants saw only one order, with the exception of one small group of participants in the main experiment, and the participants from the Gaithersburg area in the pilot.

Appendix A also presents the general procedure for Administering the experiment, including the briefing forms.

Appendix A

Group 1 Images

Symbol Number*	Referent	Image
2B	Warning flame	ISO - flames in triangle
9C	Electricity	FMC - hand, wire
12C	Explosion	ISO - triangle and explosion
15C	Fork lift truck	Alone
17B	Safety shower	Man in shower
6	Biohazard	
23C	Safety shoes	Putting on shoe
26C	Eyewash	Eye w/spray
28B	Safety gloves	1 glove
33B	Respirator	Alone - yellow
35B	Corrosion	Bandaged hand
79	Fire Extinguisher	
31	Respirator	ISO - face mask on face
41A	Hard hat	Putting on hard hat
45B	Entanglement	Gears, arrow !
50C	Ear protection	ISO - head w/muffs
51A	No open flame	Flame, triangle, slash
60B	First aid	Hand, cross
57B	Safety glasses	ISO - glasses on head
39A	Poison	Mr. Yuk
63C	Overhead hazard	Hard hat, arrow
67B	Exit	Dot
69B	No exit	Man, door, slash
74C	No entry	Standing man, slash
76A	Slip hazard	Boot, squiggle
81A	Fall	Boot in hole
85B	Alarm	Sounder and hammer
89C	Emergency exit	Flames, figure, arrow
38B	No smoking	Dot - cigarette burning on right of slash

* The symbol number was arbitrarily assigned to each symbolic image. The letters A, B, and C refer to the image variant studied for each referent. Groups 1, 2, and 3 refer to the 3 separate image sets that were used. Generally, a given participant saw items from only one of the 3 groups.

Appendix A

Group 2 Images

Number	Referent	Image
3C	Warning flame	Red fire
8B	Electricity	Zig Zag
10A	Explosion	Stylized
14B	Fork lift truck	Driver and bystander
18C	Safety shower	Torso plus drops
4	Laser	
21A	Safety shoes	ISO - 2 shoes
25B	Eyewash	Eye with drops
29C	Safety gloves	ISO - 2 gloves
30A	Respirator	ISO - face and mask
34A	Corrosive	DoT - hand and test tube
80	Standpipe	
87	Emergency exit	Door, arrow, figure running
42B	Hard hat	ISO - hat on head
46C	Entanglement	Hand in gears - FMC
48B	Ear protection	Muffs alone
52B	No open flame	Match, slash, - stylized
20B	Do not use elevator	Flame, figure, stair, elevator
56A	Safety glasses	Glasses alone
40B	Poison	Skull and crossbones
61A	Overhead hazard	Circle and triangle
64A	Exit	
70C	No exit	Man, door, X
71A	No entry	DoT
77B	Slip	Feet, squiggle
83C	Fall	FMC - figure, ledge
84A	Alarm	Bell
88B	Emergency exit	ISO - man, door
55B	Warning	X in triangle

Appendix Items

Group 3 Images

Number	Referent	Image
1A	Combustible	Stick in fire
7A	Electricity	ISO
11B	Explosion	FMC
13A	Fork lift truck	w/driver
16A	Safety shower	Showerhead w/drops
5	Radiation	
22B	Safety shoes	1 shoe
24A	Eyewash	Head w/drops
27A	Safety gloves	Hand putting on gloves
32C	Respirator	Head and mask
36C	Corrosion	Drops and hand
49	Noise hazard	Ear and waves
19A	Do not use elevator	Flame and figure
43C	Hard hat	Hat alone
44A	Entanglement	Gears
47A	Ear protection	Putting muffs on
53C	No open flame	ISO match
59A	First aid	Cross
58C	Safety glasses	Goggles alone
37A	No smoking	ISO
62B	Overhead hazard	Crane load
66C	Exit	
68A	No exit	Man walking away from
72B	No entry	Man w/big hand
78C	Slip hazard	Man falling - surface
82B	Fall/Trip	Figure falling
86C	Alarm	Phone and flame
90A	Emergency exit	flames, figure, door
54A	Warning	Δ!

APPENDIX

Number of Symbols tested per Referent
Main Experiment

3 Symbols	2 Symbols	1 Symbol
explain	poison	radiation
electrical	general warning	laser
corrosion	no smoking	biohazard
flammable	first aid	fire exit
overhead hazard	stair in fire	hose
slip		
trip/fall		
fork lift		
entangle		
eye	4 Symbols	
head		
hand	hearing	
foot	respiratory	
no open flame	emergency exit (Five for pilot)	
safety shower		
eye wash		
fire alarm		
exit (Four for pilot)		
no exit		
no entry (Five for pilot)		

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Procedure for Administering NIOSH Experiment

During Experiment

1. Have subjects read and sign subject participation form--(protects us and them, says experiment should be safe, get them medical attention if accident occurs).

2. Have subjects read and initial privacy act form--(says their data will never be identified with them).

3. Read Briefing Form -- purpose of experiment.

4. Pass out answer sheet for Part 1; ask them to read instructions.

5. Read Briefing, Part 1--show example of knife & fork, work example. Ask for questions.

6. Show slides about one every 30 sec. Speed up as all subjects complete answers.

7. After part 1 ends allow a short (5 minutes) break.

8. Pass out Part 2--do not pass out 1 & 2 together as 2 has answers for 1. Allow subjects to read instructions.

9. Read Briefing, Part 2.

10. Show combined symbols--allow 30 sec. to 2 min. to complete per symbol (too long and will get novels on these symbols). Again speed up as subjects learn the task.

11. Collect forms.

12. Read debriefing--answer questions, provide additional information as desired.

13. If subjects can't write English you fill in the answer sheet for them--try hard not to guide them or react positively or negatively.

14. If time is very short, drop preference portion, or skip "why" part. Just have them indicate appropriate letter. Try to run preference part, as this can provide valuable information to us.

Appendix B

Wrong and Partially Correct Answers from the Main Study for each Referent and Symbol Combination

Appendix B presents a tabulation of all wrong and partially correct answers obtained during the Main study. A frequency count of the number of times each response occurred is also given. The P refers to Partially correct answers; the X refers to answers that were scored as wrong. The symbol numbers are the same as those given in Appendix A, while the alphabetic characters (A, B, or C) are the same as in both A and the Figures 1-31.

APPENDIX C

Table 1

Wrong, Partial Answers NIOSH Experienced Ss

WARNING - FLAMMABLE

Partial		Wrong	
Symbol* No.		Symbol* No.	
1A	freq.	1A	freq.
No lighted matches, open flame	17	Fire present in area	10
No smoking area	4	Hot, high temperature	3
Fire area	3	Smoking area	2
Don't throw matches	2	Chemical fire, danger	2
Dangerous flammable chemical	2	Non-flammable material	1
Temperature activated materials	1	Plane	1
		Electrical	1
	29P		20X
2B		2B	
Fire area	11	Fire present in area	30
Danger, fires	5	Fires permitted	6
No open flame	5	Fire extinguisher	2
Caution, smoking	1	Camping	1
		Fire safety	1
	22P		40X
3C		3C	
Fire area	10	Fire, open flames	24
Don't play with fire	1	Extreme heat	6
Flame hazard	1	Watch for fire	3
		Fire protection	1
	12P		34X

LASER

Partial		Wrong	
#4		#4	
Caution, bright lights	18	Radiation area	8
Shades, sunglasses required	3	Caution sunshine, glare	8
Ultraviolet	1	Explosion, explosive	5
		Caution, welding	3
		High voltage, wires	3
		Solar energy plant	2
		Snow area	2
		Flying debris	2
		No light allowed	2
		Hot - acid	1
		Lights required	1
		Wear suntan lotion	1
		Target practice	1
	22P		39X

*Symbol numbers are the same as in appendix A; alphabetic characters are also the same as in figures 1-31.

BIOHAZARD

PARTIAL		WRONG	
5 Hazard contaminents	1	5 Radiation	9
		Blades, rotating object	6
		Flying, falling objects	5
		Sharp, cutting objects	4
		Moving machinery parts	4
		Heavy machinery	3
		Spacecraft	2
		Multiple outlets	2
		Emergency vehicles, area	2
		Intersection	2
		Birds	1
		No bird watching	1
		Pulleys	1
		Work area	1
		Safety lane	1
		Low overhead tunnel	1
		Volatile chemicals	1
		Hidden camera	1
		Weird art forms ahead	1
	1P		48X

RADIATION

PARTIAL		WRONG	
6		6 Caution, fans, blades	12
		Ventilation system, fan	5
		Moving parts, shaft	4
		Hearing protection, noise area	3
		Fallout shelter	3
		Siren	2
		Planes in area	1
		Mine shaft	1
		Three roads	1
		Propane gas	1
		Lathe machinery	1
			34X

ELECTRICITY

PARTIAL		WRONG	
7A Electrical, area	6	7A Lightning	11
Electric charge, static electricity	4	Curves, corners, crooked road	5

ELECTRICITY (continued)

PARTIAL			WRONG		
7A	Electrical Panel	2	7A	Danger below, falling object hazard	4
	Electric cable below	1		Slippery, dangerous floor	3
	Lightning - high voltage	1		Down, go to lower level	2
	Do not use electricity	1		Electric ground	1
				Caution	1
				No	1
				Signal	1
				San Diego Chargers	1
				Machinery	1
				Hard hat area	1
		15P			32X
8B	Electric wire	5	8B	Lightning	12
	Electricity	4		Danger	1
	Electric Equipment, panel	3		Stairway	1
		12P			14X
9C	Electrical device, contact	2	9C	Hand danger	2
	Electrical	1		Dangerous	1
	Electric voltage	1			
	Do not touch	1			
		5P			3X

EXPLOSION

PARTIAL			WRONG		
10A	Blasting area	9	10A	Fire, combustible	6
	Explosion area	5		Beware of broken glass	2
				Star	2
				Danger or Disaster area	2
				Yield right of way	1
				Bomb shelter	1
				Location park	1
				Loud noise area	1
		14P			16X
11B	Explosion area	16	11B	Flammable, fires	5
	Blasting area	6		Caution, high tension electricity	1
				Danger	1
				Hazard area	1
		22P			8X

EXPLOSION (continued)

PARTIAL			WRONG	
12C	Blasting Zone	17	12C Breakable, shattered glass	3
	Explosion area	14	Flying stone, gravel	2
	hazardous storage	1	Eye hazard	1
			Gloves area	1
			Loud noise	1
		32P		8X

FORK LIFT TRUCK HAZARD

PARTIAL			WRONG	
13A	Tow motor, fork truck	4	13A Don't pickup by fork lift	1
	Truck crossing	2	Material handling area	1
	Equipment in use	2		
	Tow motor driver	2		
	Loading area	2		
	Yield to equipment	1		
	Slow moving forklift	1		
		14P		2X
14B	Truck, equipment crossing, roadway	9	14B Men working (watch for)	7
	Moving vehicles, equipment	8	Dangerous work area	2
	Loading area	7	Use truck lift	2
	Watch step	2	Drive carefully	1
	Fork lift	1	Do not carry load too high	1
	Machinery area	1	Fork lifts only	1
			Material handling area	1
		28P		15X
15C	Tow motor, forklift	10	15C Forks down or too high	2
	Loading, unloading area	6	Don't use fork lift	1
	Vehicle road, crossing	2	Use fork lift	1
	Yield to fork lifts	2	Warehouse	1
	Fork lift drivers in area	1	Material handling area	1
	Moving equipment	1	PRT station loading	1
		22P		7X

SAFETY SHOWER

PARTIAL			WRONG	
16A	Shower	30	16A	Sprinkler system control 6
				Falling water, wet area 6
				School zone 1
				Light broken 1
				Wear water protective gear 1
				Magnets being used 1
				Poor lighting 1
				Area of Spillage 1
				Overhead crane 1
				Acid 1
				Bench area 1
		30P		21X
17B	Shower	31	17B	Water pipes 1
	Shower, pull down handle	9		
	Contamination clean-up area	1		
		41P		1X
18C	Shower	35	18C	Sun lamp, bright lights 3
	Wash area	1		Watch for falling objects 2
	Eye wash			Shower room, bathroom 2
				Low light area 1
				Correct lighting on job 1
				Wet 1
				For fire 1
				Cleanliness 1
				12X

DO NOT USE ELEVATOR IN CASE OF FIRE

PARTIAL			WRONG	
19A	Fire escape	34	19A	Get out, leave 3
	Fire stairs	23		Watch out for fires, danger 2
	Fire exit	11		Do not run down stairway in fire 2
	This is exit	1		Go for help 1
				Slippery, inflammable 1
		69P		9X

DO NOT USE ELEVATOR IN CASE OF FIRE (continued)

	PARTIAL			WRONG	
20B	No fire exit	8	20B	Fire exit, blocked	5
	Fire exit	5		Do not enter	3
	Do not use elevator	4		Do not use	1
	Fire escape	2		Fire hazard	1
	Use stairs	2		House fire	1
	May not be used in fire	2		Blind man	1
		23P			12X

SAFETY SHOES

	PARTIAL			WRONG	
21A	Hard toe boots	4	21A	Leave boots, shoes here	1
	Safety Shoes	4			
	Boots required	3			
	Shoes required	3			
		14P			1X
22B	Wear your boots	17	22B	Safety	1
	Safety shoes	7		Walking trail	1
	boots	2		Shipping and loading	1
				Shoe store	1
		26P			4X
23C	Wear boots	29	23C	Rubber boots required	11
	Protective footgear	4		Wear hip boots	1
				Caught in drive chain	1
		33P			13X

EYEWASH

	PARTIAL			WRONG	
24A	Wash eyes	1	24A	Water fountain	5
	Face wash present	1		Eye & nose are running	3
	Wash area	1		Watch for eyes, mouth	2
				Overhead hazard area	2
				Weighing scales	2
				Oil chain	1
				Respirator needed	1
				Liquid flow	1
				Hoist block & fall	1
				Hot metal or crane	1
				Toilet	1
		3P			20X

EYEWASH (continued)

PARTIAL		WRONG	
25B Eye Sprinkles	1	25B Eye irritation, danger	11
		Wear eye protection	11
		Do not rub eye	1
		Water spraying	1
		Kleenex	1
	1P		25X
26C Eye washing	1	26C Eye protection should be worn	16
Wash eye out in emergency	1	Eye hazard, material splashing	12
		Someone watching you	3
		Blinding light	1
		Slippery when wet	1
		Gas pump	1
	2P		34X

SAFETY GLOVES

PARTIAL		WRONG	
27A Work, safety, gloves	5	27A Acid or hot	1
Rubber gloves required	3	Crane signal	1
Hand protection	1	Washing facility	1
High voltage gloves	1		
Protective gear required	1		
	11P		3X
28B Gloves	1	28B Direction, follow	2
Rubber gloves required	3	Stop	5
Protective equipment	1	Left turn	2
Safety sock	1	White glove test	1
		Work area	1
		Glove storage	1
		friendly people	1
	6P		13X
29C Work, safety gloves	4	29C Wash your hand	2
Use rubber gloves	2	Handle with care	1
Sanitation, wear gloves	1	Watch fingers, hands	1
		Hot area	1
	7P		5X

RESPIRATORY PROTECTION

	PARTIAL			WRONG	
30A	Noxious fumes, dangerous pollutants	19	30A	Dust	1
	Respirator, safety mask	2		Water hose, no	1
		21P			2X
31	Face protection, mask must be worn	6	31	Sand blasting area	1
	Nose protection, mask, respirator	4		Painting or spraying	1
	Breathing protection	2			
		12P			2X
32C	Gas, toxic fumes, unsafe air	17	32C	Chemical hazard	1
	Mask required	1			
	Breathing equipment	1			
	Safety mask	1			
	Gas mask location	1			
		21P			1X
33B	Respirator, gas mask location	6	33B	Scuba gear, diving	4
	Chest protection required	2		No space crafts	1
	Wear head, face protection	2		Robot ahead	1
	Breathing Apparatus	2		Electronic gear	1
	Welding mask	1		Train area	1
	Oxygen required	1		Street light ahead	1
				Tunnel, turn on lights	1
				Wet place	1
				Goggle protection required	1
		14P			12X

DANGER, CORROSIVE HAZARD

	PARTIAL			WRONG	
	Acid	7		Treatment of hand injuries	1
34A	Location of chemicals	3	34A	Laboratory	1
	Do not touch, hand danger	2		Wash hands	1
		12P			3X

DANGER, CORROSIVE HAZARD (continued)

PARTIAL		WRONG	
35B High hand hazard area	14	35B First Aid	36
Watch getting hand burned	1	Danger, pinch points machinery	5
		Turn, left, right	5
		Danger, think	4
		Stop, halt	4
		Bandaged hand	4
		Hand danger, injuries	2
		Emergency	1
		Palm reading	1
		Unprotected hands	1
		Safety gloves	1
		Steel construction area	1
		Ho Jos	1
	15P		66X
36C Acid	8	36C Caution, sharp, cutting machinery	5
Dangerous area for hands	2	Emergency hand wash area	4
Use gloves	2	First aid	3
Acid wash area	1	Raw cut	1
		Asbestos protection	1
	13P		14X

NO SMOKING

PARTIAL		WRONG	
37A No Cigarettes	1	37A Lit Butt	1
	1P		1X
38B None		38B Cigarette Smoke	1
		Smoking Area	1
			2X

POISON

	PARTIAL			WRONG	
39A	Caution, toxic, chemical fumes	3	39A	Bad day, unpleasant area, ugly faces, unhappy people	11
	Bad water	3		Gas, fumes in the area	6
	Do not eat or drink	1		Caution, bad taste, bad food	5
				Hazard or vomit areas	3
				Danger, caution	3
				Smile, good attitude	2
				Poison center	1
				Face protection	1
				Need lights	1
				Sun exposure	1
				Face mask area	1
				Desert area, no water	1
				Moving rollers	1
				Ghost area	1
				Cafeteria ahead	1
				No licking your eyebrows	1
		7P			40X
40B	Danger, may cause death	1	40B	Danger	18
				Death, if you enter	1
				Yield to elderly	1
		1P			20X

HARD HAT REQUIRED

	PARTIAL			WRONG	
41A	Hard hat	2	41A	Wear hair protection	2
				Dressing area	1
				Respirator area	1
				Ear protection	1
				Hold onto hat	1
				Safety gear	1
				Somebody broke their heart	1
				Watch for robbers	1
		2P			9X
42B	Hard hat	9	42B	Construction worker	1
	Head protection	1			
	Wear hat	1			
		11P			1X

HARD HAT REQUIRED (continued)

	PARTIAL			WRONG	
43C	Hard hat	7	43C	Safety glove-dangerous	1
	Protective headgear	2			
		9P			1X

ENTANGLEMENT

	PARTIAL			WRONG	
44A	Moving gears	5	44A	Machinery in use	15
	Look out for machines	5		Machine shop	1
	Guard gears	1			
	Caution, shut machine off	1			
	Unsafe Equipment	1			
	Rotating machinery	1			
	Observe machine shop precautions	1			
		15P			16X
45B	Turning rotating wheels	5	45B	Turning, rolling objects, circles	8
	Grinder present, be alert	1		Think, danger, caution	5
	Dangerous machinery	1		Intersection, no turns	4
				Explosives being used	2
				Going either or both way	2
				Moving fast, slow down	2
				Turn around area	2
				Machines in area	2
				Protective eyegear required	2
				Dressing room	2
				Safety signals	1
				On and Off switches	1
				Go in right direction	1
				Use walkway only	1
				Sex education	1
				Congested area	1
		7P			36X
46C	Be careful with dangerous machinery	8	46C	Machinery area	1
	Keep guards, shield closed	3			
	Do not touch, keep hands out	2			
	Hands in gears	1			
	Gears squashing	1			
	no loose clothing near machinery	1			
		16P			1X

EAR PROTECTION REQUIRED

PARTIAL			WRONG	
47A	Ear protection	6	47A Quiet - broadcast on air	1
			Head protection	1
			eye protection required	1
		6P		3X
48B	Ear, hearing protection	3	48B Tunnel	3
	Ear muffs	1	Hearing aid	1
			No U-turns	1
			Quiet zone	1
		4P		6X
#49	Ear protection	1	#49 Listen	4
			Audio alarm, bell ring	2
			Sound vibrations	1
			Radio waves	1
		1P		8X
50C	Ear protection	10	50C Hearing (test)	2
			CO in single	1
		10P		3X

NO OPEN FLAME

PARTIAL			WRONG	
51A	Danger of Fire	13	51A Fire, open flames	4
	No smoking	6	No fire hazard	1
	No matches, cigarettes, combustibles	3	No flammable material	1
	Do not fire	1		
		24P		6X
52B	No smoking	10	52B No campfires	1
	No matches, flammables	7	Match	1
	Flammable area	3	Watch out for fires	1
	Fire, careful	2		
		22P		3X

NO OPEN FLAME (continued)

PARTIAL			WRONG		
53C	No matches, combustibles	12	53C	Fire, fire material	2
	No smoking	10		No campfires	1
	Flammable materials, hazard	3			
	No fires	2			
		27P			3X

GENERAL WARNING

PARTIAL			WRONG		
54A	Think	2	54A	Stop	3
	Watch for anything	1		Ball park	2
	Remember what we said	1		Excitement area	2
	If you are not sure, don't use it	1		Overhead in operation	2
				Information/exclamation area	2
				Key hole	1
				Unfinished road	1
				This test	1
		5P			14X
55B	Don't do whatever you are doing	1	55B	Restricted area, keep out no entry	25
				Dangerous crossing, intersection	18
				Do not yield	5
				dead end, no access, no right of way	5
				Do not proceed, cross	4
				Unsafe to use, do not touch	2
				Do not	2
				Yield, at crossing	3
				Don't go far	1
				Railroad area	1
				Road ahead	1
				First aid station	1
				No caution	1
				Place here	1
				No cooking, camping	1
		1P			71X

WEAR SAFETY GLASSES

PARTIAL			WRONG		
56A	Safety glasses	9	56A	Delicate work	1
	Eye protection	2			
		11P			1X

OVERHEAD HAZARD (continued)

PARTIAL			WRONG		
			61A	Restricted area	1
				Passage narrows	1
				Attention	1
				Safe water	1
				Safety area, no food or water	1
				Pointed objects	1
				Sunken light for heliopod	1
				Question	1
				Base	1
				Balance materials	1
				Safety triangle	1
				3-corner room	1
				No mooning	1
				Watch out for fast wheelchairs	1
				No caution signs ahead	1
				Open can of beer	1
		1P			54X
62B	Hoisting material area	2	62B	Broken cable, bad strap	3
	Loading area	2		Pick up help	1
	Hazardous cargo area	1		Don't pick up by crane	1
	Overhead objects	1			
	Caution, broken lift	1			
		7P			5X

EXIT

PARTIAL			WRONG		
64A	One way exit	8	64A	One way only	15
	Go to opening, proceed this way	4		Narrow passageway	8
	Bottleneck exit	2		Aisle, walkway, throughway	3
	Parking lot exit	1		Enter	2
	Entry	1		Turn left	1
	Emergency exit right	1		Go slow	1
	Doorway for traffic flow	1		Don't block exit	1
				Stright ahead	1
				Parking area	1
				Hidden doorway	1
		18P			34X
63C	Hard hat area	40	63C	Dead end	1
	Watch head	1		Ventilation draft	1
		41P			2X

WEAR SAFETY GLASSES (continued)

PARTIAL		WRONG	
57B	Safety glasses, eye protection 7 Wear glasses 1 Eye glasses 1 Possible eye damage area 1 10X	57B	None
58C	Eye protection, safety glasses 7 Safety goggles 4 Eye glasses 1 Flying chips 1 Safety mask required 1 14P	58C	Wear mask 1 1X

FIRST AID

PARTIAL		WRONG	
59A	Safety station, department 2 Safety cabinet 1 Hospital/safety zone 1 4P	59A	Safety 6 Crossroad, intersection 4 White, red cross 2 12X
60B	Hand first aid 11 Emergency or help 1 Hospital 1 Red cross helper 1 5P	60B	Watch fingers, danger 4 Hand safety 2 Broken finger 1 Be careful 1 8X

OVERHEAD HAZARD

PARTIAL		WRONG	
61A	Overhead work 1	61A	Yield 8 Caution, danger, hazard area 8 Going down, hole 4 Something on floor, watch step 3 Fallout shelter 3 Toxic hazardous materials 3 Radiation 2 Limited visibility, dark area 2 Explosion 1 Caution, machinery 1 Tunnel 1 Direction 1

EXIT (continued)

	PARTIAL			WRONG	
67B	none		67B	Don't exit, enter	7
				Roadway, highway	7
				Civil defense, safe shelter	5
				Go, straight	4
				Don't cross, pass, start	4
				Proceed, cross w/caution	2
				Divided building, split decision	2
				High flight pad	1
				Squeeze hazard	1
				Watch out for flying pool balls	1
				Sorry	1
				Green sign with white line	1
				Slippery, caution	1
				Volatile chemical hazard	1
				Water outlet	1
				Radio active material	1
				Railway	1
				OK to do something	1
				Caution vertical beams	1
				No Chinese allowed	1
					44X
66C	Doorway	2	66C	Men's room	1
	This way to door	2		Decontamination station	1
	Fire door	1		Dead end	1
	Use this door	1			
	Opening ahead	1			
		7P			3X

NO EXIT

	PARTIAL			WRONG	
	Locked Door	3		Fire Door	15
68A	Locked door, do not enter	1	68A	Keep door to area locked	14
				Secure, protected area or door	6
				Prison, jail	5
				Shut, close door	5
				Tool room storage	1
				Burglar	1
				Emergency Exit	1
				Entrance	1
				Hazard material area	1
		4P			50X

NO EXIT (continued)

	PARTIAL			WRONG	
69B	Don't use, stair, door	3	69B	No running	10
	Do not enter (door)	3		Slippery, tripping hazard	8
	No passage, thoroughfare	2		No loafing, standing, waiting	4
	No doorway	1		Danger crossing, do not cross	3
				Exit, exit slowly	2
				Don't go this way	1
				Danger, construction	1
				Open doorway	1
				Danger, stairs	1
		9P			31X
70C	Do not open, use door	22	70C	Shut door in unsafe area	1
	Door block or not usable	2			
	No passage	1			
		25P			1X

NO ENTRY

	PARTIAL			WRONG	
71A	Stop	4	71A	Hallway, passageway, walkway	5
	Wrong way	3		Bright light, red light	4
	Danger, stay away	1		Beware, caution, danger	3
	No Russians allowed	1		No way out, dead end	2
				Red dot	2
				Crossroad	1
				Low ceiling	2
				Red rubberball	1
				No turn	1
				Caution area, go slow	1
				No gum	1
				Operation	1
				Narrow	1
				Stay in the line	1
				No smoking	1
				Blocking symbol	1
				May be safe	1
				Eye shield	1
				Don't do something	1
				Open trench	1
				Jap meatball after treaty signed	1
				Unlevel area	1
		9P			34X

NO ENTRY (continued)

PARTIAL			WRONG	
72B	Stop, halt	69	72B Quiet, no noise	3
			Wear hand and ear protection	2
			Slow down	2
			Stop, pedestrian crossing	1
			Caution, men at work	1
			Wash hands	1
			No glove area	1
			Don't do that	1
		69P		12X
74C	Stop, look	1	74C Do not cross	2
	No walking	1	No running, loitering	2
	Do not open	1	Safety walking	1
			Don't step out	1
			Wear protective clothes	1
			Pedestrians	1
			Red cross area	1
			Caution, welding area	1
			Caution, door opening	1
			No elevator	1
		3P		12X

SLIP HAZARD

PARTIAL			WRONG	
76A	None		76A Wear boots	3
			Danger, snakes may bite	2
			Sticky area	1
				6X
77B	Be careful of material, things on floor	2	77B Housekeeping, keep area clean	2
	Loose rug	1	Stuff, flood from pipe	1
			Watch for equipment	1
		3P		4X
78C	Ice, freeze area	1	78C Rock, ledge area	2
	Watch for trip hazards or floor obstructions	1	Hit hard	1
			Disabled person in bed	1
			Safety	1
			Watch for falling objects	1
			Safety belt area	1
		2P		7X

FIRE EXTINGUISHER

PARTIAL		WRONG	
79 Fire equipment	2	79 Fire hazard area	1
		Fire oxygen	1
		Gas available here	1
	2P		3X

STANDPIPE CONNECTION

PARTIAL		WRONG	
80 Fire equipment	3	80 High pressure	1
Hose, hydrant	2		
For fire	2		
Fire protection station	1		
	8P		1X

FALL

PARTIAL		WRONG	
81A Stair, steps (falling down)	9	81A Boots (rubbers) required	2
Hole in floor	7	Safety shoes required	1
Uneven pavement, floor	4	Applying brake	1
Indented area	1		
Hazardous trenches	1		
	22P		4X
82B Watch for drop off	1	82B Hazard, danger area	3
Danger of falling from area	1	First aid	1
High point	1	Disabled people	1
		Climbing	1
		Working area	1
	3P		7X
83C None		83C Use ladders as needed	1
		Guard rails	1
			2X

FIRE ALARM CALL POINT

PARTIAL			WRONG	
84A	Warning if bell is ringing	6	84A Noise area, use hearing protection	26
	Fire department	2	Bells ringing	13
	Fire bell	1	School zone	6
	Excessive loud alarm	1	Church, steeple	4
			Signal, siren	2
			Overhead crane	1
			Loud speaker	1
			Fire hose	1
			Use caution when bell is ringing	1
		10P		55X
85B	Warning bell or signal device	2	85B High noise, use ear protection	19
	Listen for alarm	1	Bell	5
	Ring bell with hammer	1	Grinding wheel	4
			Machine, notating shaft	2
			Fire caution	2
			Vibration upon striking	2
			Saw/cutting blade	1
			Shattering materials	1
			Danger sign	1
			Work area	1
		4P		38X
86C	Telephone	2	86C Woman on the phone	1
	Emergency, fire emergency	2		
	Ranger station phone	1		
		5P		1X

EMERGENCY EXIT

PARTIAL			WRONG	
87B	Use door	2	37B Do not run	7
	Open doorway	1	Restrooms	3
	Go to nearest exit	1	*[illegible] exit	1
	Passage	1	To playground	1
			Obstacle in way	1
		5P		13X

EMERGENCY EXIT (continued)

	PARTIAL			WRONG	
88B	Doorway	5	88B	Don't run	16
	Safe to use door	1		Signal alarm	1
	Proceed straight ahead	1		Hurry through door - electric eye	1
	Normal passage	1		Narrow passage	1
				Enter	1
		8P			20X
89C	Fire protection this way	1	89C	Fire hazard area	4
	Turn left in case of fire	1		Run, keep away from fire	3
		2P			7X
90A	Get out-fast-fire	3	90A	Fire - run	2
	Fire door	1		Beware - fire	2
	Dangerous-be ready to exit	1		Fire equipment room	1
				Get out	1
				Do not open doors if fire	1
		5P			7X

Appendix C

Tabulated Preference Data and Stated Reasons for Choice

Table C presents the tabulated preference data and the stated reasons given by the participants for their various choices. These data again derive from the main experiment, rather than the pilot. The symbol identifiers, such as A, B, or C, again refer to the identifiers given in figures 1-31. The numbers following the letters refer to the number of participants choosing each of the alternative choices. The numbers following the stated reason are the number of participants giving that particular reason for their choice.

HAZARD PREFERENCE DATA

REASONS FOR CHOICES

FIRE HAZARD

A-12 **

No reason	9
Flame and matches	1
Should be red and white	1
All choices are the same	1

B-113 **

No reason	55
Clearer, easier to distinguish	15
Looks like fire	5
Color and shape (imply caution)	10
All are good	5
A, C not good	7
Good, best symbol	6
Standard sign	3
Poor symbol	1
Should be red	5

C-93 **

Red color	46
No reason	28
Clearer, more understandable	6
Nice lines, good visual understanding	7
Looks more like fire	3
None of them	2
All tell hazard	1

EXPLOSION HAZARD

A-10½ **

More noticeable, representational	5
No reason	3
More widely used	1
Color	½
Best of three	1

B-85 **

Looks more like explosion	16
No response	35
Clearer, vivid, easier to understand	16½
Color (implies hazard)	7
Liked it better	5
All bad	5
Indicates greater hazard	1

C-124½ **

No reason	51½
Looks more like explosion (debris)	28
More easily understood	10
Looks good, best sign	10
Triangle implies caution	8
Yellow implies caution	6
Rest are no good	5
Use red background	4
can be seen better	2

** Refers to the number of participants selecting each image. A,B,and C refer to the image itself as identified earlier in the report.

ELECTRICAL HAZARD

A-20

No reason	7
Color and shape	6
Clarity, more noticeable, outline	3
Depicts hazard best	2
Shows area	1
All good	1

B-25

No reason	9
Looks like electricity, sparks	5
Large and clear	5
Looks like lightning	3
Significance already established	2
Don't like A or C	1

C-176

Hand and wire	51
Wire, hot wire, shows electrical	40
Better graphics, explicit design	15
Other symbols don't look like electricity	9
More understandable	21
Do not come into contact with - turn off power	9
No reason	24
Like better	5
Show in black and yellow triangle	1
More commonly used	1

CORROSION

A-173½

No reason	55
Clearer, more believable	30
Shows consequences	11½
Color	6
Surround shape	3
Shows chemicals dripping	14
Shows two types of hazards	27
Testtube alerts to hazard	5
Best	8
All could be improved	2
Red would be better	1
More symbolic	4
Others look like cuts	1
Standardized symbol	6

B-4

No reason

C-39½

No reason	20
More descriptive, understandable	6
Larger concentration of effect	7
Shows consequences	3½
Better than A or B	2
None very clear	1

SLIPPERY

A-21

No reason	15
A is best (others OK)	2
Yellow signifies caution	2
Others OK	1
Tilted boot and skid marks	1

B-84

No reason	20
More eye catching	11
Shows action and consequences	11
More understandable, clear	11
Shows slip hazard	8
(Bigger), picture of feet slipping	13
Better looking, more detail	3
All are good	2
Be more careful	1
Use yellow background	1

C-117

No reason	35
Shows person falling, consequences	33
Most understandable-clearest	11
Color and shape	9
Better drawn, more detail	5
Standard symbol	4
Others could mean trip	2
Full body shown	6
Best	9
Don't like any	1
A and B look like shoe store ads	1
Be careful in this area	1

FALL

A-45

No reason	22
Shows hole, tripping hazard	15
More understandable	3
Combine A & C, could be better	1
B and C could mean slips, or other things	3
Color and details	1

B-112

No reason	42
Triangle and color	18
Shows person falling	20
Clearer, better, more understandable	23
Combines tripping and falling	4
Need something else	2
Need object by feet	1
No real color	1
Standard symbol	1

C-56

No reason	20
Clearly shows falling	15
Clearest, better	14
Shows high place, elevation	2
Shows severity of hazard	2
Shows open area	1
Shows tripping	1
None real good	1

FORK LIFT TRUCK

A-132½

No reason	58
Clearer, easiest to visualize most understandable	20
Looks more like a forklift	7
Person driving forklife	11
Shows forklift in use	5
Shape and color	7½
Better than C or B	14
Shows two types of forklifts	1
A and C both good	2½
Standard symbol, highway sign	3
Shows more hazard, caution	2
All good	1
As long as you know what you are looking at	½

B-69

No reason	27
Red signifies danger	18
Best, clearest, more informative	11
Shows hazard most clearly	4
Human involvement	4
Shows more than 1 type of forklift	3
No foot traffic	1
Looks like it	1

C-18½

No reason	7
Simple, easy to understand	4
Shape and color	2½
All good	4
Clear of forklift	1

OVERHEAD HAZARD

A-1

Simple and can be used internationally	1

B-154½

No reason	54
Clearest, easiest to understand	20
Depicts hazard better	35
Shows overhead object, need to look up	37½
Color and shape	5
Broken cable	2
Standard symbol	1
It is in the middle	1

C-66½

No reason	32
More understandable	7
Consequences clear	8
Shows object falling on person	9
Hard hats also needed	4
Better than A or B	4
Needs to be yellow	1
Careful where you walk	1
Depends on overhead hazard	½

POISON

A-10

More easily recognized by kids	5
Tongue more defined	1
New sign	1
Bad	1
No reason	2

B-136

No reason	77
Symbol widely known and recognized	54
Best, most easily understood, more impact	23
Idea of death, danger, skelaton	28
Shows poison	18
A not clearly a hazard	9
Neither	2
Combine both	1

ENTANGLEMENT

A-25½

No reason	10½
Indicates opening gearing, machinery area	5
Broader meaning - no injury shown	1
Red	4
Clearer	3
Should have hand in gear	1
Still isn't clear	1

B-10

No reason	6
Shape and color	2
Just like it	1
Don't like any	1

C-184½

No reason	61½
Shows consequences, hand in gears	74
Looks painful, dangerous	15
Easy to visualize, clear	24
A and B are confusing	4
Neither is particularly clear	1
Color should be red	2
Best size	1
Could be drawn better	2

GENERAL WARNING

A-89

No reason	39
Neither is good	19
Exclamation point shows urgency gets attention	7
Indicates caution	7
Needs better symbol, unfamiliar	4
Best, easily understood	8
B looks like crossing	2
Symbol shows generalities	1
Good use of visual aids	1
This symbol with caution written would be good	1

B-66

No reason	31
Both are bad	10
X indicates not to do something, danger, stop	6
X more familiar	2
More understandable, graphic	6
A doesn't imply warning, looks like exclamation point	3
Better of 2 bad signs	4
Vague, confusing	2
Covers everything	1
If that was the code	1

NO OPEN FLAME

A-94½

No reason	35
Excludes all flame, not just matches	25
Clearer, easier to see	7
Less confusing, best, easier to understand	7
Depicts flame better	10
Others look like cigarette, could mean no smoking	4
A and B together would be better	2½
Could be better illustrated	1
None are good	2
B could be used	1

B-101½

No reason	41
More graphic visible	15
Shows "no open flame" better	13
Shows matches, beware	12
Easiest to understand	10
Have seen before	3
Could also mean no smoking	3
All good	3½
Don't like A or C	1

C-19

No reason	8
Match clearer	4
Best, easiest to understand	5
A is poor	1
Match is out	1

NO SMOKING

A-78

No reason	43
Cigarette most realistic	10
Best, better graphics	15
Attracts eye, preferrable	3
Circle, slash	2
Bigger picture	1
Why not	1
Both OK	1
B could resemble a building	1
Both could be improved	1

B-123

No reason	57
Better graphic, more visible, clearer	30
Looks more like cigarette	10
Better, easiest to understand	4
Black on white background	6
I've seen it	4
Both good	6
Horizontal representation easiest to read	1
Should be everywhere	1
Looks like cigar	1
Line doesn't cross smoke	1
Why not	1
First one I've seen	1

EYEWASH

A-69½

No reason	21
Shows basin, real equipment	15
Best, self-explanatory	10
Shows person washing eye	12
Could be drawn better-head, eye	5
None good	3
Don't take chances	1
Shows head	1

B-72

No reason	33
Clearer, more descriptive	7
Easier to understand	4
Better symbol	8
Shows eye and water	12½
All are poor	4
More human	1
Could be improved	1
All are good	½
Not all eyewash equipment looks like this	1

C-68½

No reason	30
Clearer, more understandable	13
Eye and fountain clearest	11½
Better (eye)	10
Color	1
Looks like a torch	1
Universal sign	1
Combine A and C	1

SAFETY SHOWER

A-3

No reason	1
Good, but lacks person	1
Clarity	1

B-186

No reason	74
Person actually using shower	24
Person in shower (with clothes)	13
More information, more detail	31
Clear, best, most understandable	22
Shower clear	13
Relates better to safety	4
C could be a light	2
C also good	1
Used in plant	1
A and B don't look like shower	1

C-33

No reason	20
Clearer - more understandable	8
Graphic, good contrast, more visible	4
Concise	1

FIRST AID

A-131

No reason	58
Standard sign	40
Red cross sign, medical assistance	12
Best, easily understood	11
Looks good, most visible	4
Should be red	2
Both poor	1
More specific	1
Don't like hand, fingers in B	1
Both good	1

B-88

No reason	34
Shows (completed) first aid	24
Shows hurt hand, minor injury	10
Shows A plus more	6
Best, better understood	10
A would be red cross to color blind	1
A looks like safety symbol	1
Didn't understand A	1
Both OK	1

EAR PROTECTION REQUIRED

A-146

No reason	58
Shows gear on, being put on, person	40
Better, more detailed	16
Easiest to understand	20
Draws attention to ear	3
Shows protection clearly	3
All are good	3
Like cartoon man	1
B looks like tunnel - not good	2

B-38

No reason	19
Simple, most visible	9
Descriptive, understandable	5
Most frequently seen	1
Symbol alone	3
Person with muffs	1

C-37

No reason	18
Simpler, clearer picture	7
Man with ear protection	4
Shows ear muffs	2
Best, easier to understand	4
Should be in yellow triangle	1
Hands in "A" covers ear protection	1

FOOT PROTECTION REQUIRED

A-32

No reason	19
Best easiest to understand	4
Shows hard toe	3
Looks like safety shoe	3
Two shoes more explanatory	1
All good	1
None good	1

B-50

No reason	25
Simpler easier to read	14
Best, easily understood	4
Boot stands out	3
Shows hard toe	2
Need yellow and black triangle	1
Need better sign for shoe	1

C-135

No reason	57
Action of putting boot on	35
Boot and person	7
Best, most meaningful	26
Safety boot needed	3
Rest poor, look like shoe store ads	3
All are good	2
All are poor	1
Eye catching	1

HAND PROTECTION

A-177

No reason	70
Shows action, person and gloves	68
Better, clearer, easier to understand	30
All are good	3
Shows need for hand protection	3
Looks more like gloves	1
A and C about same, show 2 hands	1
Selection needs to be better	1

B-26

No reason	10
Simple, clear, sufficient	9
Easily understood	5
All good	1
Covers more of hand	1

C-14

No reason	6
Shows two hands	4½
B might mean halt	1
Best	1
All good	1
A and C about same	½

HEAD PROTECTION

A-65½

No reason	21
Shows putting hat on	16½
Best most understandable	9
More graphic, detailed, easy to see	12
Modern hard hat	4
Define hat better	1
Would like to see triangle	1
In our plant	1

B-52

No reason	28
Shows hat on person	14
Shows hat, what to wear	2½
Simple, easiest to recognize	5
Best	2
More widely used	½

C-103½

No reason	34
Best, most recognizable	16
Most plain, clear, visible	19
Hat, what's needed	18
Most direct version of message, face and hands clutter	6
Familiar	5
A and B poor	2
Would be better if yellow	1½
Should be in Triangle	1
Would be good standard sign	1

EYE PROTECTION REQUIRED

A-23½

No reason	12
Glasses alone significant	3
Clear, simplest	4½
More distinctive, visible	3
B and C could have other meanings	1

B-85

No reason	35
Shows person wearing glasses	28
Indicates eye protection must be worn	6
More meaningful, understandable	11
Standard symbol	1
More for our type work	1
Simpler, clear, better	3

C-112½

No reason	49
Safety goggles imply eye protection	14
Looks more like safety equipment	9
Shows possible debris	1
Clearer, more understandable	11½
In colors of hazard, caution signs	10
Would prefer triangle	1
Best of three	10
Most common	5
All good	1
Could be better	1

RESPIRATOR REQUIRED

A-137½

No reason	56½
Clearer, easier to understand	18
Person and mask	17
Head more pronounced	5
Detail of mask	18
Best	14
More familiar	3
B and C imply eye coverage, scuba gear	2
B - bad	1
No smoking	1
All choices good	2

B-20½

No reason	6½
Looks more like respirator	8
Eye catching, best graphics	2
Says caution with yellow background	2
Needs human figure	2
Used in our plant	1
	1

C-61

No reason	26
More easily understood	10
Good mask	13
Simple and basic	4
Face and mask, better	3
Can be seen further away	1
Looks like spaceman, could be better	2
B not bad	1
Most familiar	1

USE ELEVATOR IN CASE OF FIRE

A-48

No reason	19
More understandable	12
Clear, easier to spot at a glance	8
Shows person using stairs	2
More familiar	2
Steps and flame	3
Best choice, but does not say "do not use elevator"	1
Fire is to close in B	1

B-170

A looks like fire exit	1
No reason	54
Indicates do not use elevator	37
More meaningful	26
Shows both meanings	19
Better	14
A could mean don't use stairs	2
Clearer, more detailed	6
Shows man on stairs	3
Could be clearer	2
Marking on door	1
Both poor	1
Could mean any type of emergency	1
Red stands out, refers to fire	1
Redo colors	1
A not bad	1

FIRE ALARM

A-28

No reason	11
Shows bell	8
Better than others	2
More understandable	1
Don't like any	5
Fire truck	1

B-104

No reason	24
More understandable as alarm	40
Better than others	11
Hammer and bell, sound	9
Not easily recognized	6
Best of a bad lot	3
Others are for fire	1
Indicates call in location	2
None	3
Clearer	2
C looks like FD telephone	2
A and B are good	1

C-76

No reason	23
Shows fire, phone	16
Indicates warning alarm location	12
Clear, more visible	6
Most understandable, better	6
None really good	4
International sign	1
A and B look like hearing danger	2
Unclear	2
Need alarm instead of phone	1
Needs to be more explanatory	1
Should be in a triangle	1
Only if fire phone present	1

EMERGENCY EXIT

A-118

No reason	47½
Shows both emergency & egress	14
Better characterized	19
Red implies urgency, emergency exit	15
Shows more of a danger situation	4½
More meaningful	11
Shows door	1
All good	1
Person escaping	5

B-48

No reason	22
Green shows go, safety	11
Others restricted to fire exit	5
Man running out door	3
Best, illustrative	4
Colors could be better	2
All are good	1

C-53

No reason	27½
Shows emergency and Direction	14½
Simple easily understood	4
Like different colors, stand out	3
Others imply panic	1
Need something else	2
A good	1

GENERAL EXIT

A-28½

No reason	15
Arrow points opening	6
Easier to understand	2½
Shows you where you are	1
Don't really like any	1
Poor sign	1
Others vague	1
Resembles E for exit	1

B-5

No reason	2
Reverse of no entry	1
International usage	1
All choices poor	1

C-173½

No reason	48
Shows figure and direction	31
Shows door way out	31
Better, others confusing	26
More meaningful	19½
All bad	14
Prefer words	3
More detailed than A	1

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here*)

Written signs are commonly used in industrial sites to provide hazard warnings and safety information. The use of safety symbols may increase the effectiveness of safety communication, because such signs are language-free, and because they can be recognized more rapidly and accurately than written text even under some conditions of interference and distraction. The effectiveness of safety symbols critically depends upon the selection of symbolic images which are readily understandable to the intended audience. A four phase evaluation of a set of selected industrial worksite symbols is described. The four phases involved identification of 33 key safety messages, selection of candidate symbols for each message, evaluation of the understandability of the candidate symbols, and determination of the preference for the 87 candidate images, using both industrial and nonindustrial (naive) personnel. Symbol understandability, in terms of percentage of correct responses and confusions, varied widely for the thirty-three referents. Despite standardized use for a number of years the radiation, biohazard, and laser symbols were frequently misidentified. Symbols for protective gear, first aid, and emergency equipment were generally correctly identified. The different images selected for various hazards show the greatest range in understandability, with the results for symbolic versions of entanglement, electricity, corrosion, and overhead hazard being quite different. The most frequentl correct image was usually also the most preferred.

12. KEY WORDS (*Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons*)

communication; hazard; pictogram; safety; signs; standards; symbols; visual alerting; warnings

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