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Evaluation of Safety Symbols

Belinda L. Collins
Brian C. Pierman

Environmental Design Research Division
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Washington, D.C. 20234

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U.S. DEPARTMENT OF COMMERCE
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

The increasing use of symbols to convey fire safety information nonverbally is described. In addition the trend toward international standardization of symbols is discussed for transportation and other systems. The need for further research on symbols is discussed in terms of the advantages and disadvantages of symbol use. Advantages include rapid and accurate communication without the barriers of verbal language. Disadvantages include the too rapid proliferation of different symbols and inappropriate or misleading application. Furthermore, the failure to evaluate the understandability of each symbol is cited as a major problem. A case study which documents some of the advantages and disadvantages of a set of proposed fire-safety symbols is presented. Finally, areas for further research on symbol evaluation are discussed.

Key Words: Communication; Evaluation Methods; Fire Safety; Hazard Warnings; Pictograms; Safety Information; Standardization; Symbols.

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This report was originally prepared for the Proceedings of the Second International Seminar on Behavior in Fire Emergencies.

SI CONVERSION

The units and conversion factors given in this table are in agreement with the International System of Units or SI system (Système 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 (in^2) = 6.4516* x 10^{-4} $meter^2$
1 square foot (ft^2) = 0.0929 $meter^2$

Volume

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

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* Exactly

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1. INTRODUCTION

1.1 BACKGROUND

Information to guide, protect, or inform building users has traditionally been provided by written signs in buildings in the United States. Recently in Europe, however, there has been a tremendous growth in the use of symbols, or pictograms, to convey such information. This effort began with the development of standardized traffic symbols in Europe in the early 1900's. Now there are international standards for symbols for worker safety, hazardous materials transport, and health-care facilities, while still other standards are under consideration for fire safety alerting.

The desire to communicate information among all people everywhere through the use of symbols was most forcibly voiced by Margaret Mead and subsequently by Henry Dreyfuss (1972). Mead felt that the development of a coherent set of pictograms would be the basis of an international language (Mead & Modley, 1968). She believed that this language could solve the problems of misunderstanding and semantic confusion which exist internationally.

The current efforts aimed at the development of symbols and standards for symbol use are less ambitious, but they are still intended to reduce confusion and speed communication. At this point, there is an increasing use of symbols within the United States for transportation systems, hazard warnings, worker safety, and fire safety, as well as for public information. For example, the Department of Transportation (DoT) has successfully sponsored the implementation of standardized symbols for motorists, and has proposed other symbols for public information in transportation facilities. Increased concern for worker safety, consumer protection, and other key issues has sparked awareness in the U.S. of the concept of symbols as a viable means of communicating essential information.

Further evidence of the increasing interest in symbol use can be seen from the various national and international groups that are developing standards for symbols. At the national level, the American National Standards Institute (ANSI) has recently chartered the Z 535 Committee on Safety Colors, Signs and Symbols, while the National Fire Protection Association (NFPA) has sponsored a subcommittee on Visual Alerting Signs and Symbols. Both of these committees are working toward the development of voluntary standards for worker safety and fire safety symbols. The Society of Automotive Engineers (SAE) has also sponsored the development of a set of standard automotive symbols. In the international realm, the United Nations (UN) has developed signs and symbols for labelling hazardous materials for transport. Finally the International Standards Organization (ISO) has three committees dealing with standards for symbols. These include the Technical Committee (TC) 21 on Equipment for Fire Protection and Fire Fighting; TC 80 on Safety Colors and Signs; and TC 145 on Graphic Symbols. Again, each of these committees is concerned with the development of standard symbols.

1.2 ADVANTAGES OF SYMBOLS

Symbols can provide emergency, directional, and instructional information concerning buildings, products, and transportation systems to a wide variety of people. As noted earlier, a major impetus for the use of symbols has been the need to communicate essential information without the use of words (Kolers, 1969; Modley, 1966). For example, symbols have been widely used in Europe because international travel is commonplace and language barriers are widespread. In the United States, moreover, the percentage of the population whose native tongue is not English, but Spanish, French, Vietnamese, etc. is increasing. For these people, as well as for illiterate or verbally handicapped persons, symbols can communicate information without the use of written words.

Symbols can also be an extraordinary medium for communicating a visual message rapidly and accurately (Dreyfuss, 1966; Smith and Weir, 1978). Symbols are recognized more rapidly and accurately, in some cases, than the same message in words (Walker, Nicolay, and Stearns, 1965; King, 1975; Brainard, Campbell & Elkins, 1961). For example, Janda and Volk (1934) found that the reaction time for highway information was shorter for a symbol on any shape sign than for any combination of words and symbols, or for words alone. Thus the use of a directional arrow was found to be more effective than the words "turn here" or "road curves here." In fact the arrows were recognized more rapidly than the conventional and more familiar "STOP" sign. In addition, Walker, Nicolay, and Stearns (1965) found that symbolic road signs were recognized significantly more accurately than word signs alone. They also determined that their subjects could remember the meaning of a previously unfamiliar set of symbols with 100% accuracy after an interval of 24 hours. Smith and Weir (1978) suggested that symbols for road traffic signs are superior to verbal messages in terms of more rapid response time and recognition distance. Symbols can be also used to minimize confusion among alternative choices, moreover (Green and Pew, 1978). Smillie (1978) found response times to be faster for symbols when stress was introduced as a variable. Accuracy, however, decreased for both printed words and symbols. Finally at least one researcher (King, 1975) has suggested that symbols could be more effective than words under interference conditions. King (1975) also determined that symbols were recognized more accurately than word signs under short display conditions (1/18 sec) while King and Tierney (1970) found that symbols were more effective than words in conveying a desired meaning. These data indicate that symbols can convey information both accurately and rapidly. Under many conditions they can be more effective than words in communicating a small amount of information. These experiments did not even assess the most likely advantage of symbols over words; namely, that symbols can successfully communicate a particular message to people who do not all speak the same language.

1.3 PROBLEMS CONNECTED WITH THE USE OF SYMBOLS

Despite the potential effectiveness of symbols, there are some difficulties connected with their development and use. These problems relate

primarily to the application of symbols, rather than to the intrinsic ability of symbols in general to convey information. One of the most critical areas concerns the lack of standardization. Each person, agency, industry, etc. who feels the need for a symbol develops one, often without consultation with any other group. There is little, if any, coordination on the kinds of information which should be symbolized, or agreement on which particular sets of symbols should be used. While there have been attempts to compile listings of symbols (Dreyfuss, 1972), these are not complete, as new symbols have been generated subsequently in response to specific needs. In addition, while various international organizations such as the International Standards Organization (ISO), the Common Market (EEC), and the United Nations (UN), have attempted to standardize sets of safety symbols, most of these standards are not yet in force in the U.S.

For example, the Department of Transportation (DoT) commissioned the development of a set of 34 public information symbols to be used in transportation facilities such as airline, bus, and train terminals. While these symbols are intended to be used in such facilities, there is no guarantee that they will be used in other places where public information is provided; nor is the set complete, as it excludes fire and hazard alerting. The unfortunate possibility exists that building owners and the like will continue to use their own sets of symbols, since the DoT work is strictly oriented toward voluntary application. Thus the lack of standardization of symbols within the U.S. means that several different symbols may be used to convey a particular meaning.

A related problem connected with the application of symbols is the tendency for a symbol which has been used successfully in one application to be used in a quite different set of circumstances. For example, the "no entry" symbol (see Figure 1), originally intended for vehicular traffic, is now being considered for pedestrian traffic. Granted, there is a large measure of information transfer in that many pedestrians are also licensed drivers; nevertheless, the symbol may not be entirely appropriate, or understandable for pedestrian users. Furthermore, the "no entry" symbol may be intended only for vehicular traffic in some instances, and for all traffic in other situations.

Still another problem has arisen in which a particular situation is represented by several unique symbols. Thus, there are at least five proposed symbols for "exit" (see Figure 2), each with a very different representation of this idea. Needless to say, the potential for serious confusion is high.

Finally and most importantly, because symbols are typically developed and implemented in response to an individual and specific need, their effectiveness in communicating information to a larger audience is rarely evaluated. Although the creator of the symbol may understand its message perfectly, this message may not be communicated to anyone else. A prime example is a fire-safety symbol proposed by ISO TC 21 which means "no exit" (see Figure 3). In some instances, in fact, a symbol (and this is one) may communicate a meaning that is opposite from

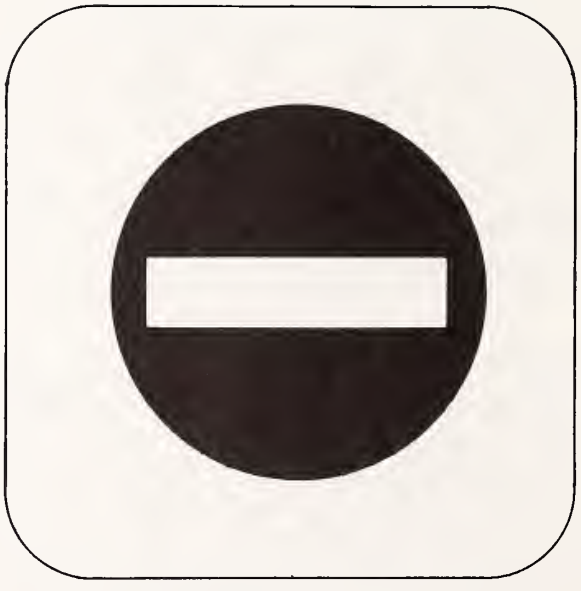

FIGURE 1. NO ENTRY SYMBOL

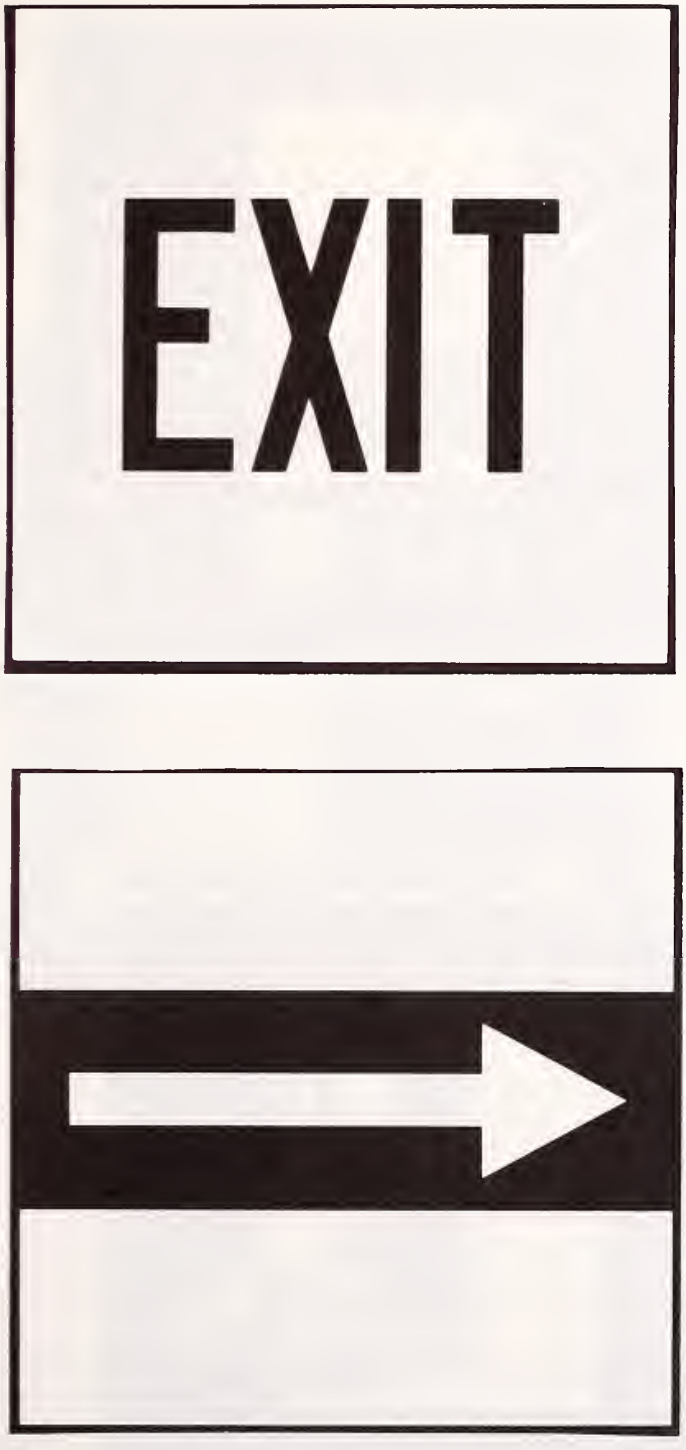

FIGURE 2. EXAMPLES OF EXIT SYMBOLS

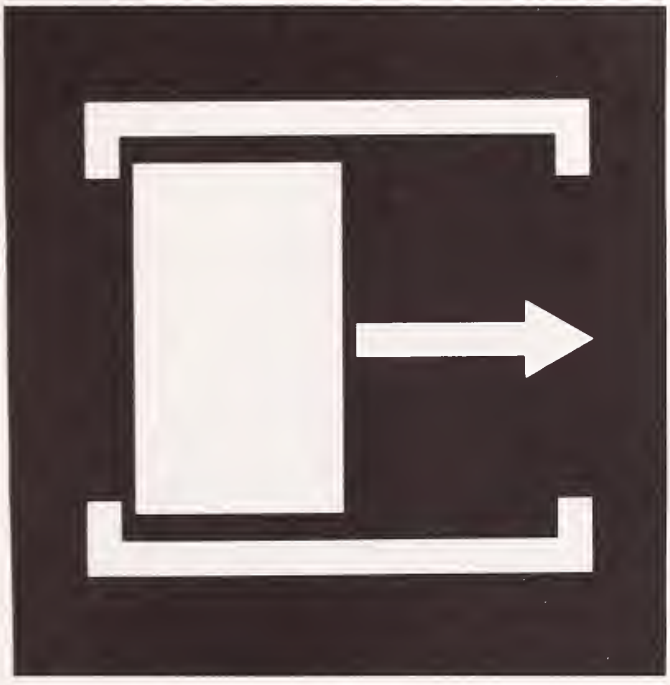

FIGURE 2 - CONTINUED

FIGURE 3. NO EXIT SYMBOL

that which is intended. Apparently, this symbol can convey the meaning of "safe refuge" to some people. Failure to evaluate the effectiveness of a particular symbol is perhaps the most serious issue in the application of symbols and the development of national and international standards.

In the preceeding paragraphs, issues related to the effectiveness of symbols for communicating specific information have been raised. In addition, various problems relating to the application of symbols were discussed. These include a lack of agreement upon which situations need to be symbolized; the proliferation of symbols and symbol-producing groups; the development of confusing and contradictory symbols; and, most importantly, the failure to evaluate each symbol's ability to communicate a particular message to a given audience. These problems can seriously hamper the transmission of essential safety information. Yet these problems can be resolved through evaluation and testing, and through the development of (voluntary) standards for symbol use. The issues raised here primarily concern the application of symbols and should not detract from the documented effectiveness of a carefully developed and researched symbol to convey urgent information accurately and rapidly. (See Section 1.2).

2. CASE STUDY

In the second portion of this report, we will present a case study which illustrates many of the issues associated with symbol use. The symbols in question are a set of fire safety symbols now being considered as a draft international standard by the ISO TC 21 subcommittee on Fire Safety Symbols.

Input from the United States as one of the 84 members of ISO was required for the preparation of an ISO TC 21 standard on Fire Safety Symbols. Yet a preliminary inspection of these symbols suggested that a number of them might not be readily understood by people in the U.S. Furthermore, this set of symbols had never been evaluated or tested for its effectiveness in communicating the specific information intended. Consequently, there were no data that indicated whether these symbols did convey the desired safety information accurately.

2.1 PROCEDURE

Under sponsorship of the NFPA subcommittee on visual signs and symbols, 22 fire safety symbols were evaluated for their accuracy and ability to convey fire safety alerting information. In this effort, 143 subjects, in a total of ten groups, were questioned about their understanding of these symbols. Although subjects were volunteers from a college community, a retirement home and several fire stations, no attempt was made to ensure that the subject selection process was at all random or representative.

The symbols were presented one by one, as placards (.3 m x .3 m or 1' x 1') at a distance of no greater than 9.1 m or 30' from the

subjects. Subjects were asked to write down a short definition of each symbol immediately after it was presented. They were allowed the option of "I don't know" as a response. The entire experiment including instructions lasted for about 45 minutes.

The responses were assessed by three judges who matched the answers against a predetermined meaning given by ISO for each symbol. The symbols were rated as "correct", "incorrect", or "no response". Agreement between two of the three judges was required for each final rating. The frequency of each type of rated response was recorded for each symbol. The percentage of subjects responding in each of the three ways was calculated for each symbol. In addition, where subjects responded incorrectly, the number and kind of alternate meanings were also tallied. Pictures of selected symbols which caused definite understandability problems are presented in Figure 4.

2.2 RESULTS AND DISCUSSION

Table 1 presents the percentage of subjects (N=143) who responded correctly to six of the proposed ISO Fire Safety Symbols. These symbols were selected for this table to show the extremes of response. Thus, the symbol for telephone and the conventional EXIT sign were recognized by almost all of the subjects. (In fact, the only people who missed these signs were several persons from a retirement home who may not have understood the instructions, although many of the retired people performed well.) On the other hand, almost no one understood the blind alley symbol. Similarly, the ISO exit symbol, the "break glass" symbol, and the "do not block" symbol were recognized by only 20-25% of the 143 subjects. Pictures of all the symbols tested are provided in Appendix A, along with the percentage of correct recognition.

The results indicate that there are are serious drawbacks to the immediate use of some of the proposed ISO Fire Safety symbols in the U.S. At least several of the symbols were not understood by a large majority of subjects (under these testing conditions). These include the "exit," "no exit," "fire ladder," "break glass" and "do not block" symbols. In addition, not only were several symbols incorrectly identified, in some cases they were given a meaning opposite to that which was intended. Thus, the "no exit" sign was interpreted as exit or safe area by almost 70% of the 69 subjects who identified this symbol incorrectly. It should be noted that about 140 of the 143 subjects either misidentified or did not respond to this particular symbol. Yet it should also be noted that 95% of the subjects were able to identify the "telephone" and "no smoking" symbols correctly, as well as the word "EXIT." This recognition rate is well above the 75% recognition rate set by Heard (1974) as required for adoption of automotive symbols.

The results reported here are very preliminary, and are given only to provide an indication of the range of effectiveness which may be expected when symbols are used the sole means of conveying information. Thus, several of the symbols were accurately understood by the majority of the subjects. Other symbols were either not known, or, more

ISO EXIT

BREAK GLASS TO OBTAIN ACCESS

FIGURE 4. SYMBOLS RESPONDED TO INCORRECTLY

BLIND ALLEY--NO EXIT

DO NOT BLOCK--KEEP PASSAGEWAY CLEAR

FIRE LADDER

FIGURE 4 - CONTINUED

TABLE 1. PERCENTAGE OF SUBJECTS WHO RESPONDED CORRECTLY TO SIX OF THE PROPOSED ISO FIRE SAFETY SYMBOLS. SEE APPENDIX A FOR PICTURES OF THE SIX SYMBOLS.

seriously, were identified with a meaning opposite to that intended. While a fairly large number of people from a variety of backgrounds were tested, this was by no means a random or representative sample of subjects. Consequently, these results do not apply for all people in the U.S., and are not intended to provide a definitive answer to the fire safety symbols problem. They do indicate, however, the urgent need to evaluate the understandability of each symbol before it is used for a hazard warning. If a symbol does poorly during the evaluation, then redrafting should seriously be considered. If the symbol cannot be redrafted, then an intensive educational effort must be implemented.

3. GENERAL DISCUSSION

An instance in which a symbol is given a meaning opposite to that intended illustrates the most serious problem with the use of symbols. Yet, this type of situation can arise when symbols are neither developed nor evaluated consistently. The potential for serious harm in a case such as the "no exit" symbol which was interpreted as "safe haven" is very great. Consequently, before symbols are adopted, particularly ones which relate to emergency situations, their effectiveness in communicating the desired safety information to the intended audience must be evaluated. Ideally, the evaluation process should occur during the initial drafting stages, and again before implementation to eliminate serious misidentifications.

An evaluation program for proposed safety symbols should provide evidence of each symbol's effectiveness for conveying information to a particular audience. If the symbol is not deemed effective, then one of two courses of action can be implemented. The first is to institute an intensive education program to teach people the meaning of the symbol, after which its effectiveness should be reevaluated. The second is to use information gained during the evaluation program (such as misidentification) to modify and improve the symbol. Again, the modified symbol must be evaluated before it is implemented. It is especially critical to evaluate <u>new</u> symbols and sets of symbols before they are used to convey safety information.

4. RESEARCH PROGRAM AT NBS

As a result of the need to implement more effective symbols, NBS has begun a research program in which safety symbol use will be evaluated. Five major questions will be addressed in this program. These include: (1) which situations, or groups of situations, require symbols, (2) how do users evaluate specific symbols, (3) what are the methods and criteria for evaluating symbol effectiveness for these situations, (4) what are the characteristics of an effective symbol, and (5) what conditions affect the usefulness of symbols? A specific focus will be the testing and evaluation of safety symbols in the workplace and under emergency conditions--with the ultimate goal being technical input into the development of standards for symbol use and evaluation.

During the symbol research program at NBS, we will develop and implement a variety of test procedures for evaluating safety symbols. As Cahill (1975) noted, the empirical validation of a symbol's effectiveness is an essential element of symbol development. Validation is a key step in determining whether a symbol accurately communicates the desired information and can affect the subsequent actions of the intended audience. Thus, Freedman, Berkowitz and Gallagher (1976) tested public information symbols by determining if these symbols were successful in guiding people through a museum. Heard (1974) assessed the effectiveness of automotive symbols by having subjects touch each control as the corresponding symbol was presented, while Easterby and Zwaga (1976) asked a wide variety of subjects to define the meaning of each of six public information symbols.

The preceding examples are presented to indicate some of the situations in which symbols have been evaluated for their effectiveness. This knowledge can then be used to improve the symbol, implement an education program, or empirically support a symbol's widespread use. In conclusion, knowledge of the understandability of a given symbol, particularly a safety symbol, is essential before it is used. The development of standard evaluation procedures is seen as a critical factor in this process. The NBS research program will provide information on the use of different evaluation techniques, as well as data on the understandability of specific safety symbols.

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APPENDIX A

In the following pages 21 photographs of the 22 fire-safety symbols used in this experiment are given. (The EXIT sign which was presented in both red and green type is only shown once.)

Under each photograph is presented the percentage of subjects (N=143) who responded correctly with an accurate definition of the symbol.

1. EMERGENCY EXIT

25% correct

2. FIRE EXTINGUISHER

93% correct

3. FIRE-FIGHTERS EQUIPMENT
   1% correct

4. DO NOT LOCK
   59% correct

5. DO NOT BLOCK - KEEP PASSAGEWAY CLEAR

19% correct

6. FIRE ALARM CALL POINT

8% correct

7. DO NOT USE WATER

63% correct

8. NO SMOKING

93% correct

9. NO OPEN FLAME

78% correct

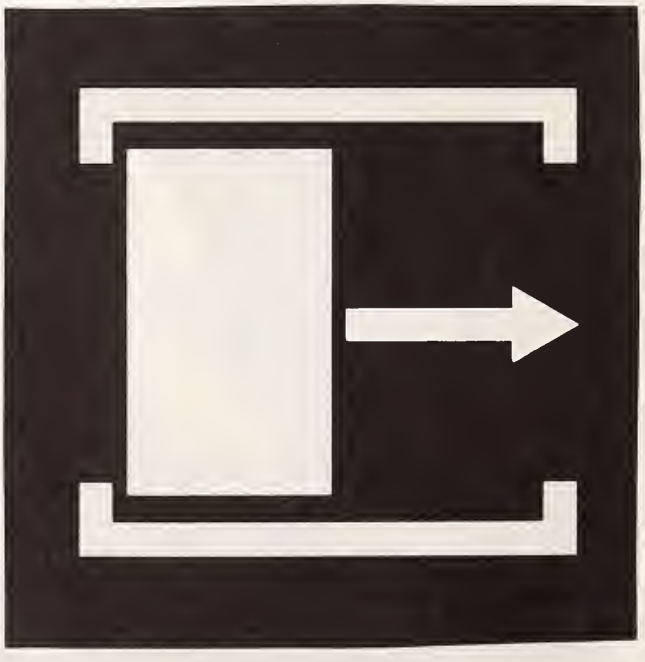
10. TELEPHONE - RED - EMERGENCY

65% correct

11. TELEPHONE - BLUE - GENERAL
94% correct

12. BREAK GLASS TO OBTAIN ACCESS
30% correct

13. BLIND ALLEY
3% correct



14. SLIDE DOOR TO RIGHT TO OPEN
23% correct

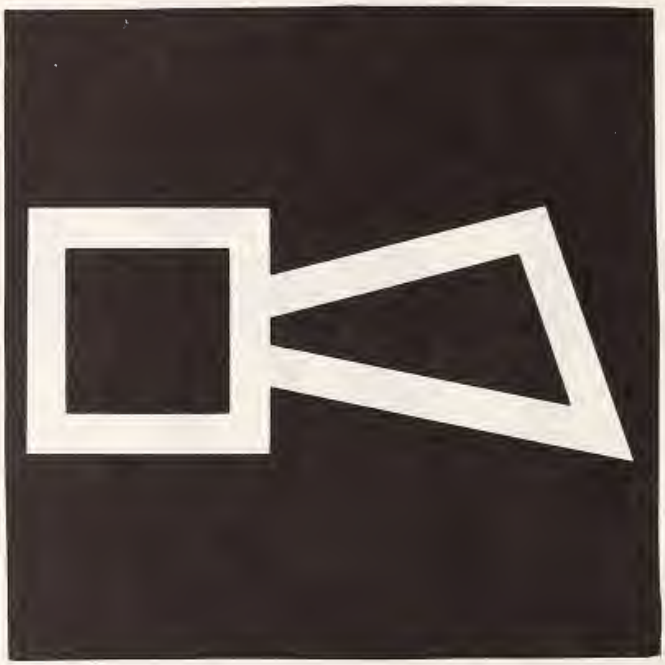
15. FIRE LADDER
57% correct

16. STANDPIPE (HOSE AND REEL)
84% correct

17. DIRECTION TO FIRE-FIGHTING EQUIPMENT
17% correct

18. FIRE BUCKET LOCATION
64% correct

19. EXIT (in words)- both Red and Green
95% and 92% correct



20. FIRE ALARM HORN
16% correct

21. FIRE DOOR - KEEP SHUT
20% correct

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

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

The increasing use of symbols to convey fire safety information nonverbally is described. In addition, the trend toward international standardization of symbols is discussed for transportation and other systems. The need for further research on symbols is discussed in terms of the advantages and disadvantages of symbol use. Advantages include rapid and accurate communication without the barriers of verbal language. Disadvantages include the too rapid proliferation of different symbols and inappropriate or misleading application. Furthermore, the failure to evaluate the understandability of each symbol is cited as a major problem. A case study which documents some of the advantages and disadvantages of a set of proposed fire-safety symbols is presented. Finally, areas for further research on symbol evaluation are discussed.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Communication; evaluation methods; fire safety; hazard warnings; pictograms; safety information; standardization; symbols.

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