PERCEIVED EFFECTIVENESS OF DANGER SIGNS: A MULTIVARIATE ANALYSIS

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ABSTRACT

Fifty-eight subjects were shown randomly-ordered facsimiles of 80 OSHA-standard danger signs and rated the signs on 13 dimensions related to perceived effectiveness. The data were analyzed by means of principal components analysis and a series of multivariate and univariate analyses of variance. Signs containing a hazard label and instructions (e.g., GASOLINE - NO SMOKING) were rated as least likely to be recalled at a later time; however, they were rated as easiest to understand, most informative, and most likely to be complied with. Signs containing a hazard label only (e.g., POISON) were rated as least informative and most difficult to understand; however, they were rated as most likely to be recalled, as depicting a high degree of danger, and likely to be complied with. Signs containing instructions only (DO NOT ENTER) were rated as generally less effective.

INTRODUCTION

There appear to be two approaches to making a product or system safe for use. First, is to design the system in such a way that potentially dangerous features are either absent or inaccessible. Second, is to provide an informative sign or tag that warns the user of a hazardous feature and/or instructs the user in the safe use of the product or system. While a worthy ideal, designing a system that precludes user injury is difficult, and the second approach is frequently necessary if safe system operation is to be encouraged.

Nationally-recognized standards for accident prevention signs have been issued by the American National Standards Institute (ANSI, 1972), the Occupational Safety and Health Administration of the US Department of Labor (OSHA, 1990), the Society of Automotive Engineers (SAE, 1987), and the Truck Trailer Manufacturers Association (TTMA, 1985). Accident prevention signs usually consist of two elements, a signal word that indicates the level or type of hazard, e.g., DANGER, WARNING, CAUTION, and a major message that identifies the hazard and/or contains instructions to be communicated to the user, e.g., HIGH VOLTAGE, DO NOT OPERATE WITHOUT GOGGLES. In some cases a sign may also include a symbol or graphic representation of the hazard. The Standards contain specific information on the physical characteristics of signs, in particular, color, lettering, layout, and proportion. However, information on the appropriate wording and content of the major message is vague. For example, the OSHA Specification states that:

> The major message shall indicate the specific hazardous condition or the instruction to be communicated to the employee. (p. 414)

The ANSI Standard adds that:

> The wording of any sign should be easily read and concise. The sign should contain sufficient information to be easily understood. The wording should make a positive, rather than a negative suggestion, and should be accurate in fact. (p. 12)

The human factors research literature provides more specific information on appropriate message wording and content. An early, often-cited study by Dorris and Purswell (1978) concluded that effective accident prevention signs should identify the hazard, describe the action to be taken in order to avoid injury, and be readily understood. Recent experimental evidence (Wogalter, et al., 1987) has reinforced and extended Dorris and Purswell's conclusions. The maximum perceived effectiveness of a warning sign is achieved when each of the following elements is present: (1) a signal word, (2) a hazard label, (3) a consequence, and (4) instructions for avoiding the hazard, the most important elements being the label and the instructions. Additional factors that influence warning effectiveness include the perceived hazardousness of a product, its familiarity, whether the sign is noticed or read, and the ease of complying with the warning message. The influence of other attributes, such as symbols, pictographs, highlighting, size, and lettering is uncertain (DeJoy, 1989).

An important consequence of having vague standards for the wording of accident prevention signs is that a wide variety of wordings is admissible, thus making it difficult to choose or design the most effective wording for a particular situation. The present study was conducted to help alleviate this difficulty. Our strategy was to measure the cognitive responses to a large, representative sample of accident prevention signs, worded in accordance with the recent OSHA Specification (1990). The questions addressed by this study included: (1) Are there distinct classes or categories of signs, which nonetheless meet the standard guidelines? (2) Do signs that meet the standard guidelines differ in their perceived effectiveness, and, if so, in what ways?

METHOD

Subjects

The subjects, introductory psychology students at the University of Dayton, were 58 undergraduates (18 males and 40 females) ranging in age from 18-21. They participated in order to partially fulfill a research requirement for the course.

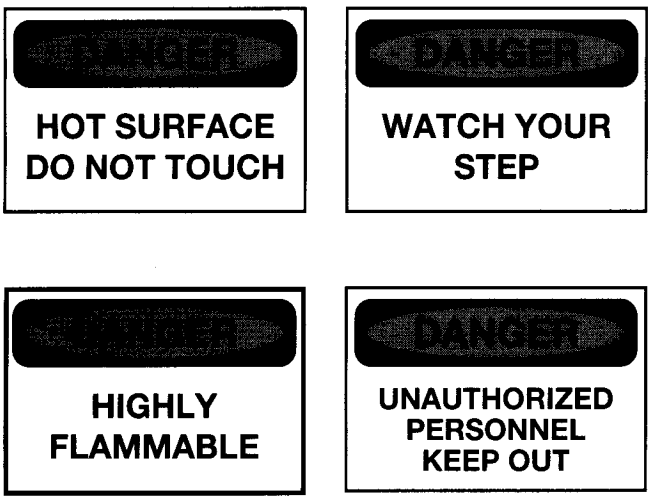

Figure 1. Sample facsimiles of standard danger signs used in this study.

Stimuli

The stimuli were facsimiles of 80 accident prevention signs containing the signal word "DANGER." (See Figure 1 for samples.) The signs were randomly chosen from the compilation of OSHA-standard signs contained in the Identification Products Catalogue of the Seton Name Plate Company (New Haven, CT).

Procedure

Each subject was provided with a randomly-ordered booklet depicting one of the 80 sign facsimiles at the top of each page followed by list of 13 questions, viz.,

1. How likely would you be to recall this sign at a later time?
2. How clear an idea do you have of the hazard depicted in this sign?
3. How much danger is associated with this hazard?
4. How familiar are you with the hazard depicted in this sign?
5. How likely would you be to comply with this warning?
6. How concise is the wording on this sign?
7. How likely would it be for a person to be injured if he/she ignored this sign?
8. How easy is it to understand this sign?
9. How informative is this sign in helping you to avoid the hazard?
10. How strong is the wording of the message considering the true level of danger?
11. How well does the sign attract your attention?
12. How much effort would be required to avoid the hazard?
13. How authoritative does the sign appear?

Table 1
Examples of Signs Loading High on Each of the Primary Components

Component I - Signs Containing Hazard Label and Instructions:
- BLIND INTERSECTION - PROCEED SLOWLY
- HIGH VOLTAGE - KEEP OUT
- HOT SURFACE - DO NOT TOUCH
- BLASTING - KEEP AWAY
- INHALATION HAZARD - DO NOT BREATHE VAPORS

Component II - Signs Containing Instructions:
- NO ADMITTANCE
- GO SLOW - SOUND HORN
- KEEP CLOSED
- NO SMOKING
- WATCH YOUR STEP

Component III - Signs Containing Hazard Label
- EXPLOSIVES
- 440 VOLTS
- POISON
- HIGHLY FLAMMABLE
- FALLING MATERIAL

A seven-point categorical rating scale, anchored by a pair of bipolar adjectives (e.g., likely - unlikely), accompanied each question. Subjects indicated their responses by marking the appropriate interval on each scale. The task was self-paced and took about 60 minutes to complete.

RESULTS

The data provided by each subject consisted of ratings (coded on a scale of 1 to 7) of 80 signs on 13 separate scales, yielding 1040 variables. A principal components analysis was computed to help summarize this large amount of data. Input consisted of a matrix of correlation coefficients that reflected the similarity in rating profiles between each pair of signs.

The analysis extracted five components, which accounted for 97.6% of the variability in the input matrix. The first component described signs that contained the greatest amount of information, typically, a hazard label and instructions for avoiding the hazard (e.g., GASOLINE - NO SMOKING); 30 signs loaded on this component. The second component described signs that tended not to label the hazard, but did contain instructions (e.g., DO NOT ENTER); 22 signs loaded on this component. The third component described signs that labelled the hazard, but contained no instructions (e.g., POISON GAS); 22 signs loaded on this component. The fourth and fifth components were considered unimportant. Only six signs loaded on these components, accounting for 6% additional variability beyond that of the first three components. Moreover, ratings reliability coefficients (Chronbach's alpha) of these six signs were generally lower than those of the other signs (below .90). Table 1 lists additional examples of the signs that loaded high on each of the three primary components.

Table 2
Summary of Multivariate and Univariate Analyses of Covariance: Mean Ratings[1] and Significance Levels

Variable	(#)	Sign Group I	Sign Group II	Sign Group III	p
Recall?	(1)	2.6	2.5	2.3	<.025
Clarity?	(2)	2.6	3.2	2.5	<.001
Danger?	(3)	2.5	3.7	2.3	<.001
Comply?	(5)	1.9	2.5	2.1	<.001
Injury?	(7)	2.4	3.6	2.5	<.001
Understand?	(8)	2.1	2.1	2.4	<.001
Informative?	(9)	2.3	3.1	3.5	<.001
Multivariate					<.001

[1]Mean Ratings (low to high) reflect greater to lesser degree of rated characteristic.

The next set of analyses was computed to identify differences among the ratings of the three primary sign groups. Input consisted of each subject's mean ratings of the signs within each of the three groups. Global significance was tested by means of a doubly multivariate repeated measures analysis of covariance. (Scale #4 was assigned as the covariate in order to control for possible differences in familiarity with the depicted hazards.) The averaged multivariate test was significant, $F(24, 204) = 15.75$, $p<.001$, with a large effect size of .65 (cf., Wilk's lambda). Univariate F-tests showed that there were differences among the ratings of the three sign groups on seven of the scales. The results of these analyses are summarized in Table 2.

A Tukey test was used to perform analytical comparisons for each of the seven scales. The results of these tests ($p<.01$, except as noted) can be summarized as follows:

1. Group I signs (those containing a hazard label and instructions) and Group II signs (those containing instructions only) were rated as less likely to be recalled at a later time than were Group III signs (those containing a hazard label only), $p<.05$.

2. Group I and Group II signs were rated as easier to understand than were Group III signs.

3. Group I signs were rated as providing the greatest amount of information for avoiding the hazard, whereas Group III signs were rated as providing the least amount of information, $p<.05$.

4. Group II signs were rated as least clear, as depicting the lowest level of danger, least likely to be complied with, and least likely to lead to injury if ignored. The ratings of Group I and Group III signs on these variables were statistically equivalent.

DISCUSSION

The results of this study provided clear answers to the questions posed in the Introduction. The principal components analysis showed that the 80 signs

could be categorized into three distinct groups, based on similarity in rating profiles. The multivariate and univariate analyses showed that the groups differed on several important cognitive dimensions.

Signs that contained both a hazard label and instructions for avoiding the hazard (Group I) were judged as highly effective in general, despite some evidence that they would prove harder to recall. The signs in this group tended to reflect most of the attributes of effective warnings identified by Wogalter, et al. (1987) and DeJoy (1989). Signs that contained only instructions (Group II) were judged to be least effective. This agrees with Wogalter, et al. (1987), who found that removing the hazard label produced the greatest reduction in perceived effectiveness. The signs that contained only a hazard label (Group III) were judged as slightly less effective than those in Group I. It is noteworthy that the absence of instructions for avoiding the hazard did not appear to compromise the perceived effectiveness of these signs. This finding is consistent with Wogalter, et al.'s (1987) contention that a familiar hazard label without accompanying instructions nonetheless allows the reader to infer appropriate courses of action.

There are several implications of the results for the design of effective accident prevention signs. Signs containing instructions only, however strongly worded, should be used with caution, particularly if the actual level of risk is high and compliance is critical. Signs containing both a hazard label and instructions appear to be the most prudent choice. However, the additional words needed to present instructions could, under certain circumstances, tax processing capacity. Signs containing only a hazard label can be highly effective, particularly if the hazard is familiar and of high risk. These signs were also judged easiest to recall, although it is uncertain whether recallability is a necessary attribute of effective warnings.

As a final caveat, it is important to realize that these conclusions are based on subjective reports. While there is some evidence that the perceived effectiveness of warnings is correlated with actual compliance (Wogalter, et al., 1987), a clear relationship has not been established.

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