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Roger C. Jensen

Montana Tech of the University of Montana

Andrew M. McCammack

Montana Tech of the University of Montana

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Safety and Health Sign Colors and Signal Words for Communicating Information on Likelihood and Imminence of Threat

R.C. Jensen, Ph.D.; Montana Tech of the University of Montana; Butte, Montana
and
A.M. McCammack, M.S.; Montana Tech of the University of Montana; Butte, Montana

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Abstract

Signs are used extensively in workplace facilities and on products to identify hazards and provide instructions and safety information. A fundamental component of these signs is a signal-word panel located at the top of the sign. Certain colors and signal words in this panel are intended to convey information about a hazard, including likelihood of harm and imminence of the threat. The purpose of this study was to determine if young adults without prior training on safety signs associate signal words and color with likelihood of harm and imminence of the threat. The sample population consisted of 59 college students. Subject rated their impressions of ten signs using ordered rating scales. Results indicated that both signal word and color had highly significant effects on ratings for both likelihood of harm and imminence of the threat.

Introduction

Methods for controlling hazards include engineering and behavioral methods. Every safety professional understands that engineering methods are preferred. These hazard control methods include eliminating hazards, minimizing the degree of hazard, and controlling the hazard with guards and other safety devices. Behavioral methods, while less reliable than engineering methods, play a significant role in the safety of workplaces and products. Behavioral hazard controls include establishing standard operating procedures, training personnel, providing personal protective equipment, and placing safety signs in appropriate locations. The study reported here contributes to the body of research literature aimed at optimizing the effectiveness of safety signs.

A fundamental component of safety signs is the signal-word panel located at the top of the sign. The colors and words in this panel are intended to convey general information about the subject of the sign (ref. 1). The standard of the American National Standards Institute (ANSI) for facility signs uses multi-factor categories for determining the appropriate word and color combination for the signal word panel (ref. 2). A careful reading of the specifications reveals three criteria for choosing the correct type of sign for a hazard: 1) Is it for an imminently or potentially hazardous situation?, 2) How certain is it that harm will occur?, and 3) How severe will the harm be if it occurs? The ANSI standard (ref. 2) does this using the following specifications (*italics added for emphasis*).

DANGER indicates an *imminently* hazardous situation which, if not avoided, *will* result in death or serious injury.

WARNING indicates a *potentially* hazardous situation which, if not avoided, *could* result in death or serious injury.

CAUTION indicates a *potentially* hazardous situation which, if not avoided, *may* result in minor or moderate injury, or property damage.

Thus, the signal-word panel provides certain general information about the hazard or meaning of the sign. It does not provide any information about the specific type of hazard. For example, the sign for an electrical panel normally contains the signal word DANGER on a red background because the hazard inside the panel, if contacted, is almost certain to cause death or serious injury. It is considered an

imminently hazardous situation for a person near the electrical panel because the harm would occur immediately upon contact with the hazards energy inside the panel. Information about the hazard being electrical would be placed in the text panel and/or the symbol panel of the sign. For hazards situations with less likelihood and/or less imminence, the standard specifies use of WARNING or CAUTION on an orange or yellow background, respectively. For example, a sign requiring use of hearing protection in an area with noise levels in the range of 85 to 100 DbA would normally use a CAUTION sign because noise is a *potentially* hazardous situation that *may* result in minor or moderate injury. These examples are among the more cut-and-dry situations. Many hazardous situations do not fit neatly into one of the categories. For example, a hazardous situation that is an imminent threat of causing minor injury does not fit into any of the categories. This shortcoming is discussed more completely in another paper (ref. 3).

A key reason for undertaking this study was concern that the three-criterion sign classifications system in the ANSI standard might be unnecessarily complicated. This concern is based on the underlying proposition that the reason for safety signs is to communicate with people. Specifications in the sign standards that add complexity without contributing to communication lack utility, and may unnecessarily complicate the sign classification system. Thus, this study was undertaken to determine if ordinary, untrained adults associate sign features in signal word panels with the intended concepts of imminence (i.e., imminent or potential hazard) and certainty of harm (i.e., will cause, could cause, or may cause harm). The specific sign features examined were the signal words and colors of the signal-word panels.

Research into the communication value of signs typically involves showing signs to participating human subjects and having them rate their perception on one or more rating scales. Numerous prior studies of safety signs based their comparison on ratings of *overall hazard level*. An example is an experiment reported by Wogalter, Kalsher, Frederick, Magurno, and Brewster (ref. 4). They used a sample of 112 subjects, consisting of half college students and half community volunteers. Subjects rated a variety of safety signs for *overall hazard level*. The rating scale consisted of the ordered categories: extreme hazard, high hazard, moderate hazard, low hazard, and no hazard. Their comparison of different background colors for the signal-word panel found that red rated highest, followed by yellow, orange, and black. All these colors differed significantly from each other. The lowest ratings were for purple, green, blue, and white, and these were not significantly different from one another. Their comparison of different signal words found the following order in mean ratings: DEADLY, DANGER, WARNING, CAUTION, SAFETY FIRST, and NOTICE. All signal words differed significantly from each other. Their study also found that hazard-level ratings by the college students and the community volunteers were generally consistent.

Other rating scales have been used in the numerous safety sign studies. A rating scale for degrees of likelihood has been used in at least two studies of safety signs (ref. 5-6). Silver and Wogalter (ref. 6) asked "What is the likelihood of injury implied by this term?" followed by five ordered responses: extremely likely, very likely, likely, unlikely, and never. This scale closely fit the needs of the study reported here. No prior studies were found with a rating scale concerning the ANSI distinction between an imminently hazardous situation and a potentially hazardous situation.

Methods

Subject Population: The sample population consisted of 59 college students attending Montana Tech of the University of Montana. Of the students, 52.5 percent were male (31), and 47.5 percent were female (28). Tests were conducted in a classroom. None of the 59 reported having prior training on safety signs. One subject reported red-green color blindness, but no problem distinguishing the colors used in the experiment. Each subject signed an Informed Consent Form prior to participation, and each received a \$10 stipend at the conclusion of testing.

Procedure: The experiment used a randomized complete block design (also known as a repeated-measures design). Subjects were the blocking variable and the signs were the treatments. Subjects were tested in nine small groups. After explaining the study and obtaining informed consents, students were shown

examples of what they would see and be asked to do. After the briefing, subjects were handed an answer booklet and the experiment commenced. The subjects first read a paragraph restating the instructions and answered three questions about their age, gender, and whether they had previous training in how to interpret workplace safety signs. When everyone was finished with this portion of the survey, 12 signs were shown in a predetermined random order at 45-second intervals. On a page in the answer booklet, subjects were asked three questions, each followed by a rating scale. Students viewed a sign and then rated it on each scale. This procedure was repeated for all signs. Then subjects turned to another page in their answer book containing three other questions and rating scales. Each sign was displayed again and subjects rated it on the three rating scales.

Ratings from the two scales shown in figure 1 are reported in this paper. The first scale was constructed to correspond with the ANSI standard. The second scale was a slightly modified version of the scale used by Silver and Wogalter (ref. 6). The two scales were on different pages of the answer booklet.

I feel that this sign style is most closely associated with:

- An immediate threat of harm
- A potential threat of harm
- A threat of harm to property, not humans

What is the likelihood of injury implied by this style of sign?

- Extremely likely
- Very likely
- Likely
- Unlikely
- Never

Figure 1 - Rating Scales

Materials: Five of the signs had a color for the background of the signal-word panel. The colors were red, orange, yellow, blue, and gray. The signal word was the same nonsense word (RESVRE) used in a prior study (ref. 4). These are shown in the left column of figure 2.

Five other signs had a signal word on a gray background. The signal words were DEADLY, DANGER, WARNING, CAUTION, and NOTICE. These are shown in the right column of figure 2. Two other signs unrelated to this paper were also included.

All signs had a text panel contained repetitions of the letter x in what appeared to be a sentence format. The reason for this was to make the sign appear similar to safety and health signs encountered in a workplace setting while not containing a word message that might influence ratings.

Signs were developed on computer using Maxisoft software and then printed on 8.5 by 11 inch photograph quality paper. The colors complied with those specified in the ANSI standard for safety sign colors (ref. 7). All the signal words are used in the ANSI standard for safety signs (ref. 2) except for

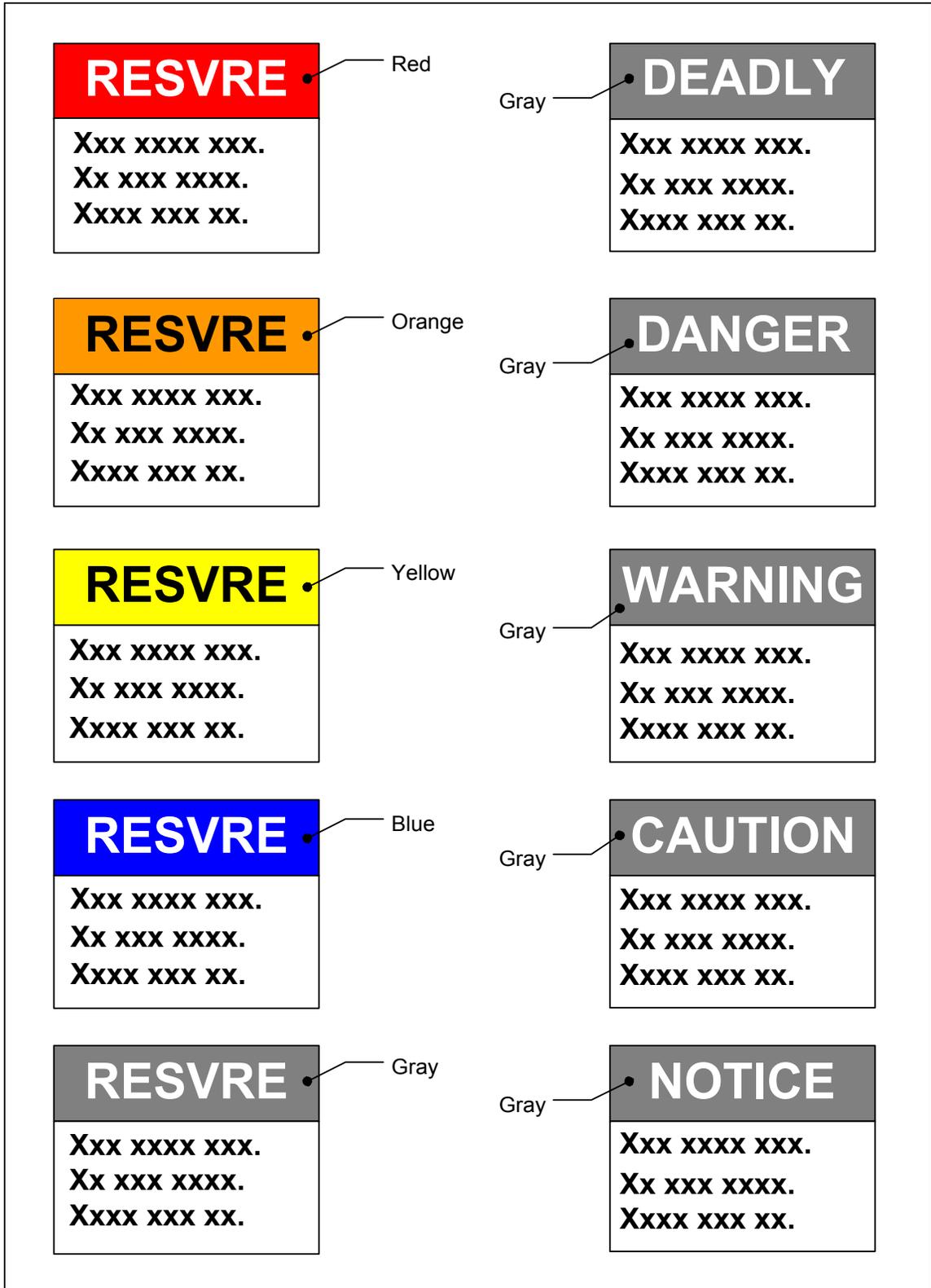


Figure 2 - Signs Tested

DEADLY, which is used because prior research shows that it might imply a greater level of hazard than DANGER (ref. 4). Signal words were printed in accordance with the ANSI standard except that NOTICE was not printed in italics as specified in the ANSI standard. NOTICE was printed in plain text in order for all signs to be comparable on word alone. The message panels of all signs consisted of black lettering on a white background to comply with the ANSI standard (ref. 2).

Statistical Analyses: Subject ratings were assigned numerical values as follows.

I feel that this sign style is most closely associated with: 0= A threat of harm to property, not humans, 1= A potential threat of harm, or 2= An immediate threat of harm.

What is the likelihood of injury implied by this style of sign? 0= Never, 1= Unlikely, 2= Likely, 3= Very likely, or 4= Extremely likely.

Data were first subjected to a Friedman Test (ref. 8). This is a nonparametric procedure analogous to ANOVA and efficient for a randomized complete block design. An analysis was performed with one of the rating variable as the dependent variable; then the other was analyzed the same way. These tests determined if color had an effect and if signal word had an effect. Statistical software called Minitab (ref. 9) was used for the Friedman Tests. Another statistical package called SigmaStat (ref. 10) was used for post hoc analysis using the Student-Newman-Keuls Tests to determine if there were significant differences among treatments.

Results

Results are presented in Tables 1 through 4. The categories of the independent variable are listed in the left column, in the expected order. The number of subjects is in the second column. The third column of each table indicates the estimated median rating for each treatment — a value calculated as the grand median plus the treatment effect. The fourth column lists the sum of ranks. If the ratings followed the expected order, the estimated median and sum of ranks would be in order from largest to smallest value. The bottom three rows of each table give the grand median, Friedman Statistic, and P-value. Statistical significance is indicated by a high value of the Friedman Statistic and a P value less than 0.05. A highly significant effect is indicated by a P-value less than 0.01. The treatments and rating scale for tables are:

- Table 1 – Color rated on the Imminence of Threat Scale
- Table 2 – Color rated on the Likelihood of Injury Scale
- Table 3 – Signal word rated on the Imminence of Threat Scale
- Table 4 – Signal word rated on the Likelihood of Injury Scale

Table 1 provides results for color effects on imminence of threat. Results were highly significant. Red rated highest, followed by yellow, orange, blue, and gray. According to the ANSI Standard, the expected order was red, then orange and yellow the same, followed by blue. Gray is not part of the ANSI standard. The Student Newman-Keuls test indicated that median ratings for every color differed significantly from those of every other color.

Table 1 - Effects of Color on Ratings for Imminence of Threat

Color	N	Estimated Median	Sum of Ranks
Red	59	2.0	262.0
Orange	59	1.0	173.0
Yellow	59	1.2	203.5
Blue	59	0.6	137.0
Gray	59	0.2	109.5
Grand median	1.0		
Friedman Statistic	118.4		
P-Value	0.000		

Table 2 provides results for color effects on likelihood of injury. Results were highly significant. Red rated highest, followed by yellow, orange, blue, and gray. The expected order was followed except orange and yellow were reversed. According to a Student Newman-Keuls test, ratings for every color differed significantly from those of every other color.

Table 2 - Effects of Color on Ratings for Likelihood of Injury

Color	N	Estimated Median	Sum of Ranks
Red	59	3.0	263.5
Orange	59	2.0	183.0
Yellow	59	2.2	203.5
Blue	59	1.0	131.0
Gray	59	0.8	104.0
Grand median	1.8		
Friedman Statistic	119.4		
P-Value	0.000		

Table 3 provides results for signal word on imminence of threat. Results were highly significant. The signal word DEADLY rated highest, followed by DANGER, CAUTION, WARNING, and NOTICE. According to a Student Newman-Keuls test, ratings for every signal word differed significantly from those of every other signal word except there was no significant difference between WARNING and CAUTION. This finding is consistent with the ANSI Standard.

Table 3 - Effects of Signal Word on Ratings for Imminence of Threat

Color	N	Estimated Median	Sum of Ranks
DEADLY	59	2.0	265.5
DANGER	59	1.0	208.0
WARNING	59	1.0	158.0
CAUTION	59	1.0	162.0
NOTICE	59	0.0	91.5
Grand median	1.0		
Friedman Statistic	147.0		
P-Value	0.000		

Table 4 provides results for effects of signal word on likelihood of injury. Results were highly significant. The signal word DEADLY rated highest, followed by DANGER, WARNING, CAUTION, and NOTICE. According to a Student Newman-Keuls test, ratings for every signal word differed significantly from those of every other signal word except there was no significant difference between WARNING and CAUTION.

Table 4 - Effects of Signal Word on Ratings for Likelihood of Injury

Color	N	Estimated Median	Sum of Ranks
DEADLY	59	3.8	279.5
DANGER	59	2.4	207.5
WARNING	59	2.0	164.0
CAUTION	59	1.8	149.0
NOTICE	59	1.0	85.0
Grand median	2.2		
Friedman Statistic	167.0		
P-Value	0.000		

Discussion and Conclusions

Results indicated that both color and signal word had highly significant effects on the two rating scales. However, this statistical conclusion serves only to justify more detailed, post-hoc analyses to develop a meaningful understanding of effects of color and signal word.

Among the colors, red received the highest ratings for both rating scales. This is consistent with expectations of the ANSI standard (ref. 2). Blue and gray had the lowest ratings on both scales, as expected.

According to the ANSI standard, both orange and yellow should indicate a *potential* threat. Median ratings for both orange and yellow were consistent with that expectation.

According to the ANSI standard, orange and yellow should differ on likelihood of injury. Specifically, according to the standard, orange is for a hazard that *could* cause injury, while yellow is for a hazard that *may* cause injury. This verbal distinction is very subtle, and probably not appreciated by the general workforce. Results from this study indicate that yellow actually rated slightly higher on the likelihood of injury scale than did orange. Thus, this finding is inconsistent with expectation based on the ANSI standard.

Among the signal words, DEADLY rated highest for both likelihood of harm and imminence of threat. Although the ANSI standard does not include DEADLY, the finding is consistent with the study by Wogalter et al. (ref. 4). Ratings for DANGER were lower than DEADLY and higher than other signal words for both rating scales. Ratings for WARNING and CAUTION were not significantly different on the imminence of threat scale. This is consistent with the ANSI standard because both words are for *potential* hazards. Ratings for WARNING and CAUTION on the likelihood scale were not significantly different from each other. Their median ratings were lower than DANGER and higher than NOTICE, as expected. NOTICE rated lowest on both scales, and this is consistent with the ANSI Standard. A NOTICE sign is not intended to mark a hazard.

In some ways, these findings support the ANSI standard. However, the findings about color bring into question the wisdom of continuing the distinction between orange and yellow signs. The concept that orange should signify something between red and yellow ought to be understood by anyone who has mixed red paint with yellow paint to obtain orange. However, with warning signs, untrained young adults do not consistently recognize the concept that orange signifies something between red and yellow.

These findings also bring into question the utility of including likelihood of injury as a third criterion for deciding which signal word to use for a particular hazard. Our subjects did not distinguish between WARNING and CAUTION on likelihood of injury. The current ANSI standard attempts to make a distinction by including the words *could* and *may* in the specifications for WARNING and CAUTION signs, respectively. The authors see no good reason for maintaining this subtle distinction in the standard.

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Biographies

Roger C. Jensen, Ph.D., Associate Professor, SHIH Dept., Montana Tech, 1300 West Park Street, Butte, MT 59701, USA, telephone - (406) 496-4111, facsimile - (406) 496-4650, e-mail - rjensen@mtech.edu.

Roger Jensen is a member of the Montana Tech faculty in the Safety, Health, and Industrial Hygiene Department. He teaches undergraduate courses in occupational safety and graduate courses in ergonomics and systems safety. Prior to this academic appointment, Dr. Jensen spent 7 years with a technical services company doing safety and ergonomics consulting, and 22 years with the National Institute for Occupational Safety and Health (NIOSH). His primary work with NIOSH was in safety research. Dr. Jensen has authored about 60 publications on occupational safety and ergonomics. He is a Certified Safety Professional--Systems Safety Aspects, a Certified Professional Ergonomist, and a Registered Professional Engineer. His education in industrial engineering includes the B.S., M.S.E., and Ph.D. degrees from the University of Utah, University of Michigan, and West Virginia University, respectively.

Andrew McCammack, M.S., completed his Masters of Science degree in Industrial Hygiene at Montana Tech in December 2001. His thesis was on safety and health signs used in occupational environments to convey information. He completed his undergraduate studies at Ball State University in Environmental Science.