Comprehension of Different Types of Prohibitive Safety Symbols with Glance Exposure

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The comprehension of 16 pictorial safety symbols was examined using a rapid visual exposure technique and 4 types of prohibitive circle-slash variants (over, under, partial, and translucent). Performance was higher for base pictorial images that appeared to depict more concrete, less complex and familiar concepts. Symbols were better understood with the under and translucent slashes. This research has implications for the design of pictorial symbols on roadways and in other environments where exposure to safety information may be brief.

INTRODUCTION

Pictorial symbols are increasingly being used to communicate important safety information in transportation, industrial environments, and consumer products. Effective pictorials allow individuals to extract critical information when needed. Environmental conditions, individual cultural experiences, visual acuity, and other factors such as aging could degrade a pictorial symbols' understandability. Sometimes pictorials are seen for short durations, such as when traveling past signs in motor vehicles. The degree to which a symbol can be both seen, understood, and responded to given a brief visual exposure may have important ramifications for pictorial design.

Avant, Thieman, Brewer, and Woodman (1986) showed that drivers with normal vision could recognize traffic signs with an exposure duration of approximately 50 milliseconds. Under such short durations, content, format, and familiarity substantially affected pictorial recognition (Avant et al., 1986; Marcel, 1983). Safety pictorials can be designed using either prohibitive or permissive approaches. The prohibitive pictorial informs the viewer about conditions that are not allowed, while the permissive pictorial informs the viewer about conditions that are encouraged. Gough (1965) suggests that positively stated concepts are more easily understood than negatively presented concepts. However, some concepts are best represented as a negation of a represented behavior (e.g., No Swimming). A red circle coupled with a red slash overlay (going from the top left to the bottom right of the circle) has become a common graphical method used to represent prohibition. Sometimes critical parts of pictorial symbols within the slash overlay could be obscured. As a consequence the intended message could be missed or misunderstood.

Dewar (1976) examined the glance legibility (identification following brief viewing) of traffic sign pictorials. He assessed four variations of the prohibition symbol: a red ring with a slash over the symbol, a red ring with a slash under the symbol, a red ring with a partial slash (stub), and a red ring only (no slash). A traffic sign pictorial was shown to participants for a period of 8 or 100 ms, and then individuals were asked to match the image with one on a sheet with numerous other traffic pictorials. The results showed greater identification accuracy with no slash or a partial slash than with the other two versions of the slash. Dewar concluded that people performed poorly with the conventional circle-slash because it sometimes obscured portions of the pictorial and increased the complexity of the image.

Murray, Magurno, Glover, and Wogalter (1998) assessed preferences for prohibitive pictorials for four slash variations and two pictorial orientations (left or right). Orientation was manipulated by rotating the pictorial on the horizontal axis such that it faced left or right. In general, Murray et al. found that the under and over slashes were the most highly preferred, followed by the translucent slash, and partial slash, respectively. Thus, the general trends of Murray et al.'s results differ from Dewar's. Murray et al. also noted a significant interaction between pictorial, slash type, and orientation

with the slash. For some pictorials, certain orientations were less preferred because the slash obscured critical portions of the symbol. This effect was largest for the over slash as compared to the other slash types. The dissimilar methods of measuring outcomes by Murray et al. and Dewar might be the reason for the inconsistent findings. Murray et al. assessed subjective preferences, whereas Dewar used a rapid exposure technique. The present study uses the same stimuli used by Murray et al., but uses a presentation method that more closely corresponds with Dewar's rapid exposure approach. Additionally, the current research uses an open-ended comprehension test procedure to assess performance. This procedure is used because it is more externally valid than the identification/matching procedure used in Dewar's study.

This research seeks to assess the glance legibility of 16 prohibitive safety pictorials found in a variety of public and industrial settings. The current study revisits three of the four slash variants originally examined by Dewar (over, under, and partial slash) while additionally assessing a fourth variant, the translucent slash examined in Murray et al.'s study.

METHOD

Participants

Sixty-four undergraduate students (34 male and 29 female) from introductory psychology courses at North Carolina State University participated for research credit.

Materials

Sixteen concepts displayed as pictorial symbols were used (see Figure 1). These are the same stimuli used by Murray et al. (1998).

Figure 1. The 16 base pictorials used in the experiment. The circle slash component was in red; the base pictorial symbol was in black

The experiment was conducted on an Apple Macintosh Power PC 7500 computer, and the stimulus presentation was automated with a software application developed using Allegient SuperCard version 2.0 (San Diego, CA). Pictorials were presented on a color Macintosh 37.5 mm (15 inch) diagonal computer monitor as black images on white backgrounds with the circle and slash presented in red. The area of red was 35% of the total area inside the outer rim of the circle, leaving 65% of the area for the pictorial in accordance with the ISO 3864 (1984) standard. All pictorials were fully contained within a red circle with an outer diameter of 11.3 cm and a slash width of 1 cm. The slash was maintained at a 45 degree diagonal from the top left to the bottom right portion of the circle as recommended by ANSI Z535.2 (1998) and ISO 3864 (1984).

Four slash conditions were evaluated: slash over (in front of) the pictorial, slash under (behind) the pictorial, a partial (broken) slash, and a translucent slash revealing the image beneath (see Figure 2). In the over slash condition, the slash was opaque where it crossed over the pictorial concealing a portion of the image. In the under slash condition, the pictorial on top of the slash was opaque and the pictorial concealed a portion of the slash. In the partial slash condition, the slash was displayed as truncated "stubs" that stopped before touching the pictorial, leaving a small amount of white space between the stub and the image. In the translucent slash condition, the intersection of the slash and the pictorial changed color to gray, showing the outline of the pictorial through that segment of the slash.

Pictorials were grouped by their approximate orientation. Orientation I generally included objects facing or turned towards the left. Orientation II had objects faced or turned towards the right.

Figure 2. Four slash conditions (over, under, partial, and translucent) for left and right orientations

Design

The experiment was a 2 (orientation: I vs. II) x 4 (slash type: partial, under, over, or translucent) balanced Latin square design. Each pictorial base image (e.g., dog, bicycle, etc.) was randomly assigned to another base image to make 8 pairs and then each pair was placed in one of 8 conditions. Each participant saw a pictorial pair in each combination of slash type and orientation. Therefore, participants were exposed to all pictorial base images and all slash/orientation variations in accordance with the Latin square, although no one saw every pictorial in all slash and orientation conditions. The dependent variable was pictorial comprehension as scored from participants' written responses.

Procedure

Participants first completed a questionnaire requesting general demographic information (e.g., gender, age). The experimenter then told the participants that the study was an investigation of people's ability to understand the meanings of various images. Task instructions emphasized that the images would be shown very quickly and only once. Initially, participants were presented with two practice trials of images that were not used in the main experiment to familiarize them with the quick presentation rate. Images were presented for a duration of 50 ms followed by a checkerboard pattern to mask or reduce post-exposure afterimages. After seeing each individual pictorial symbol, participants recorded what he or she believed to be its meaning on the response sheet. Participants' responses were graded by two independent judges as: correct, partially correct, or incorrect (scored as 1.0, 0.5, and 0.0 respectively). The inter-rater reliability (as calculated by number of agreements divided by the total items multiplied by 100) was 89%.

RESULTS

Mean comprehension scores are shown in Table 1. A 16 (pictorial base images) X 4 (slash type: over, under, partial, or translucent) X 2 (orientation: I vs. II) analysis of variance (ANOVA) was used to examine the data. A significant main effect for pictorial symbol was shown, $F(15, 896)=52.96$, $p<.0001$. In general, comprehension scores were higher for images that appeared to be simplest. Comparisons among the means using the Tukey's Honestly Significant Difference (HSD) test ($p < .05$) showed that the mean

Table 1

Mean comprehension score for each pictorial as a function of slash type

	Slash				
	Over	Under	Partial	Translucent	Overall Mean (SD)
No Left (Right) Turn	1.00	.88	.88	1.00	.94 (.24)
No Bicycling	.88	1.00	.75	1.00	.91 (.30)
No Trucks	.94	.94	.72	.91	.88 (.31)
No Dogs	.84	.81	.72	.81	.80 (.29)
No Snowmobiling	.66	.72	.50	.75	.66 (.45)
No Smoking, Eating, or Drinking	.47	.78	.38	.63	.56 (.40)
Do Not Drink the Water	.47	.63	.53	.56	.55 (.48)
No Digging	.25	.47	.34	.59	.41 (.47)
No Diving	.25	.53	.50	.31	.40 (.49)
Do Not Climb Tower	.38	.41	.31	.41	.38 (.27)
No Flames	.25	.31	.31	.47	.34 (.39)
Do Not Touch Switch	.31	.28	.19	.31	.27 (.25)
No Entrance	.22	.25	.09	.16	.18 (.24)
No Exit	.22	.06	.06	.06	.10 (.27)
Do Not Touch Exposed Gears	.03	.06	.03	.03	.04 (.14)
Keep Out - High Voltage	.00	.03	.09	.00	.03 (.15)
Mean	.45	.51	.40	.50	

comprehension scores for NO LEFT (RIGHT) TURN, NO BICYCLING, NO TRUCKS, NO DOGS, and NO SNOW MOBILING, were significantly higher than the means for all other pictorials except NO SMOKING, EATING OR DRINKING and DON'T DRINK THE WATER. The mean comprehension scores for the four symbols: NO ENTRANCE, NO EXIT, DO NOT TOUCH EXPOSED GEARS, and KEEP OUT - HIGH VOLTAGE were significantly lower than the means for all other pictorials except DO NOT CLIMB TOWER, NO FLAMES, and DO NOT TOUCH SWITCH.

The ANOVA also showed a significant main effect of slash type, $F(3, 896)=5.84$, $p<.05$. Comparisons using Tukey's HSD test showed that the comprehension scores for the under slash ($M=.51$) and the translucent slash ($M=.50$) were significantly higher than for the partial slash ($M=.40$). The over ($M=.45$) slash produced an intermediate mean score that did not significantly differ from the other conditions. There was no significant main effect of orientation, nor were there any significant interactions.

DISCUSSION

Higher comprehension scores were produced for the less complex pictorial symbols. Symbols such as dogs and trucks are familiar concepts to most people, and are also very concrete and precise in meaning. The pictorials receiving the lowest comprehension scores appeared to contain more detail than the other symbols. While this study did not include separate evaluations of the pictorial's complexity, concreteness and familiarity, the notion that these characteristics play a role in pictorial comprehension is beginning to be noted in recent research. For example, Hoonhout (2000) found results that suggest that more concrete symbols were better understood by mentally retarded children. Young and Wogalter (2001) and Kline and Fuchs (1993) found that less detailed symbols were better identified than more detailed symbols.

Higher comprehension scores were found for the under and translucent slash types compared to the partial

slash. The over slash produced intermediate comprehension. Both the under and translucent show the entire outline of the internal image whereas the over slash does not. The partial slash also shows the entire internal image, but the proximity of the white space separating the broken slash and the image might add complexity which possibly led to a difficulty in separating the figure from the ground given the short presentation exposures. The latter finding is inconsistent with Dewar's (1976) high glance legibility preference for the partial slash. The reason for this difference might be due to differences in (a) depicting the partial slash (Dewar had larger "stubs" and smaller images relative to the available space in the circle), (b) the speed of presentations (Dewar used 8 and 100 ms, whereas we used 50 ms), (c) the selection of pictorial symbols used in the two studies, and/or (d) the response method (matching vs. comprehension). The results are also mixed with respect to the over slash. In the present study, the over slash produced intermediate levels of comprehension, whereas Dewar found very poor performance for this condition, which also conflicts with Murray et al. (1998) finding of very high preference for this condition. Further investigation is needed to determine the reason for the discrepancies among the three studies. For example, it is possible that one type of slash may not be best under all circumstances. If so, it may be necessary to determine the best type of slash/pictorial combination for the expected circumstances in which the symbol may be viewed. Despite the differences between studies, all three showed relatively good performance for the under slash. Moreover, the translucent slash used in Murray et al. and the present research also performed well.

Glance legibility and understandability are an important consideration in pictorial design for roadway symbols, workplace images, and warning signs for potentially hazardous environments or situations. Pictorial designers should consider the possibility that in certain situations individuals may be exposed to a symbol for a brief duration, and from that short exposure the intended message will need to be effectively communicated. Overall, this and previous research indicate that the under and translucent slashes may be viable ways to communicate prohibition in some instances.

REFERENCES

ANSI (1998). *Criteria for Safety Symbols:* Z535.3. American National Standards Institute, Arlington, VA: National Electrical Manufacturers Association.

Avant, L., Thieman, A., Brewer, K. and Woodman, W. (1986) On the earliest perceptual operations of detecting and recognizing traffic signs. In A. G. Gale, M. H. Freeman, C. M. Haslegrave, P. Smith, and S. P. Taylor (Eds.), *Vision in Vehicle* (Vol. 1), Amsterdam: North-Holland.

Dewar, R. (1976). The slash obscures the symbol on prohibitive traffic signs. *Human Factors, 18,* 253-258.

Gough, P. (1965) Grammatical transformations and speed of understanding. *Journal of Verbal Learning and Verbal Behavior, 4,* 107-111.

Hoonhout, H.C.M. (2000). Evaluating graphical messages for mentally retarded adults; do pictures get the intended information across? *Proceedings of the International Ergonomics Association & the Human Factors and Ergonomics Society Congress, 44 (4),* 798-801.

ISO (1984). *Safety Colours and Safety Signs* (Publication No. ISO 3864). Geneva, Switzerland: International Organization for Standardization.

Kline, D. W. and Fuchs, P. (1993). The visibility of symbolic highway signs can be increased among drivers of all ages. *Human Factors, 35,* 25-34.

Marcel, A. (1983). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual awareness. *Cognitive Psychology, 15,* 238-300.

Murray, L., Magurno, A., Glover, B. and Wogalter, M. (1998). Prohibitive pictorials: Evaluations of different circle-slash negation symbols. *International Journal of Industrial Ergonomics, 22,* 473-482.

Young, S. L., & Wogalter, M. S. (2001). Predictors of pictorial symbol comprehension. *Information Design Journal, 10,* 124-132.