ELSEVIER

International Journal of Industrial Ergonomics 22 (1998) 473–482

International Journal of
Industrial
Ergonomics

Prohibitive pictorials: Evaluations of different circle-slash negation symbols

L.A. Murray[a], A.B. Magurno[b], B.L. Glover[b], M.S. Wogalter[b,*]

[a] *Department of Industrial Engineering, North Carolina State University, Raleigh, NC 27695, USA*
[b] *Department of Psychology, North Carolina State University, Raleigh, NC 27695, USA*

Received 15 October 1996; received in revised form 18 October 1996; accepted 10 March 1997

Abstract

To indicate a prohibited activity, pictorials are frequently overlaid with a red circle and 45° left-to-right slash. Previous research suggests that the combination of the slash and symbol may affect the overall identifiability of the warning. The purpose of the present research was to determine whether people's judgments of four types of the circle-slash (a slash over the symbol, a slash under the symbol, a partial slash, and a translucent slash) would differ in perceived effectiveness. Sixteen pictorials with semantically different message content (e.g., NO TRUCKS, DO NOT CLIMB TOWER), in both left-facing and right-facing orientations were viewed by 60 participants. The results revealed that the over and under slashes were preferred to the translucent or partial slashes. Both orientation and slash type influenced preference for a subset of nonsymmetrical symbols. Some of the pictorials with the over slash were given lower evaluations when critical features were concealed. The general preference for the over and under slashes may be due to familiarity and its concordance with Gestalt principles of good figures. Implications for the development of prohibitive pictorials are discussed.

Relevance to industry

Pictorials are increasingly being used to communicate safety information in cases where the target audience may use different languages. The present research examines different versions of the circle-slash negation symbol for the purpose of determining when critical pictorial elements may be obscured. Implications for pictorial recognition are discussed.

Keywords: Warning; Prohibitive messages; Signs; Safety; Symbol; Pictorial; Hazard control

1. Introduction

Warnings serve to promote safety in various environments and product-use situations. Pictorials are more frequently being used in warnings as a means of communicating hazardous conditions. As the world community continues to expand, the necessity for communicating hazard warnings to ensure the safety of consumers and workers, regardless of language, becomes increasingly important. Pictorials may help in accomplishing this goal.

* Correspondence address: Michael S. Wogalter, Department of Psychology, North Carolina State University, Raleigh, NC 27695, USA.

0169-8141/98/$19.00
PII S0169-8141(96)00029-2

Designers of warnings can use both permissive and prohibitive strategies to convey messages. The permissive pictorial provides information about conditions that are encouraged or allowed, whereas the prohibitive pictorial provides information about conditions that are to be avoided or prevented. Some research suggests that positively stated concepts are more easily understood than negatively presented concepts (Gough, 1965). However, some concepts are difficult to represent in a direct permissive way and a negation must be applied to a depicted behavior to convey the meaning of the intended message. For example, a direct permissive pictorial for No Swimming would be difficult to design; this concept is more effectively communicated by prohibition.

In recent years, it has become common practice to use a red circle with a red slash to indicate negation or prohibition. This symbol was initially promulgated in Europe and was subsequently adopted in the United States and other countries. Although standards concerning the design of pictorial warnings, such as ANSI Z535.2 (1991) and ISO 3864 (1984), recommend the use of the red circle-slash to symbolize prohibition, little research in the area of pictorial negation has been conducted.

For some pictorials, a slash overlay may obscure critical aspects of the symbol and could negatively affect comprehension of the intended concept. In earlier research, Dewar (1976) assessed the glance legibility (comprehension after very brief viewing) of traffic sign pictorials. He examined four prohibition symbol variations: 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 (stubs), and a red ring only (no slash). Participants were shown a road-sign image on a screen for either 8 or 100 ms, and then asked to pick the matching image from various traffic symbols on an answer sheet. The results showed greater accuracy with no slash or a partial slash than with the other two slash variants. Dewar concluded that people performed poorly with the conventional circle-slash because it increased pictorial complexity and obscured portions of the pictorial.

The content and structure of signs can influence the optimal extraction of information (Ells and Dewar, 1979). A warning can be confusing or ambiguous if an inappropriate pictorial is used or if critical detail of the intended message is obscured. Thus, factors that influence understandability are an important basis of pictorial research (Lanjunen et al., 1996).

The present research seeks to re-examine three of the four circle-slash variations examined by Dewar (1976) (over, under, partial) as well as a new variation, the translucent slash. The translucent slash was designed to change color or interact as it crosses the pictorial, so as to avoid obscuring important features. The effect on 16 pictorials was examined to determine whether preferences differ when some features are less visible, particularly in the over slash condition.

Pictorial orientation might also determine the degree to which important detail is concealed by a slash. Some pictorials are nonsymmetrical. With respect to the slash, the visibility of important components in these pictorials could be hidden to a greater extent in one orientation compared to another. However, other pictorials are symmetrical and therefore pictorial orientation would not be differentially affected by the slash. In the present research, nominal orientation was manipulated by rotating the pictorial on the horizontal dimension (left versus right facing). Thus, the present study examined whether judgments of effectiveness are influenced by slash type and pictorial orientation.

The placement of the slash over the pictorial was expected to be the least preferred as it would be the most likely to conceal portions of the symbols when compared with the three other types of slash conditions (Dewar, 1976). It also would reduce contrast differentiation between the pictorial and the slash, and the pictorial itself would be broken into two parts. However, the over slash might be the most preferred due to familiarity or because of its solid Gestalt configuration (Sanders and McCormick, 1993; Sekuler and Blake, 1985). Gestalt principles describe the tendency to organize perceptual information into coherent patterns based on graphic properties. Therefore, the completeness of form (non-broken parts) of the over slash could be perceived as a "good" figure and therefore receive higher evaluations. Among the three other slash versions, the following expectations were posited: (a) The under slash might receive low evaluations

because of reduced contrast due to its contiguous position relative to the pictorial, the partial concealment of the slash, and the slash's incompleteness as a Gestalt form. On the other hand, the under slash could receive relatively high evaluations because the pictorial is completely visible, and its "wholeness" could be perceived as a good figure. (b) The partial slash might receive low evaluations because of its decreased visibility due to its reduced total surface area and its perception as an incomplete Gestalt form. However, the partial slash may receive relatively high evaluations because the pictorial is completely visible, and because the slash does not touch the pictorial, thereby avoiding contrast problems. (c) The translucent slash might be most preferred because it provides the least obscuration of the pictorial and allows the underlying features of the pictorial to be seen through the slash. The reduced contrast and the possibility that it is perceived as having multiple (non-Gestalt-like) parts could reduce evaluation levels, however.

Moreover, judgments of the slash variants might also be affected by familiarity, with the over slash being more common (and more familiar) in real-world prohibition pictorials, the under slash being less common, and the partial and translucent slashes being unfamiliar. Lastly, it was also expected that effectiveness judgments could be dependent on the specific pictorial and its orientation with respect to the slash.

2. Method

2.1. Participants

Sixty volunteers in the Raleigh, NC area participated in the study. Thirty were students from introductory psychology courses at North Carolina State University, who participated for research credit. Of these, 25 were male and 5 were female, with ages ranging from 18 to 26 ($M = 19.5$, $SD = 1.8$). Thirty additional participants were attendees at a local flea market, ranging in age from 21 to 65 ($M = 38.9$, $SD = 13.2$). The flea market participants were comprised of 14 males and 16 females, and were given a token gift (e.g., a mug, a pencil, or a cap) in exchange of their participation.

2.2. Design

The experiment was a 16 (pictorial) X 2 (orientation I vs. II) X 4 (slash type: over, under, partial, or translucent) within-subjects design. The dependent variable was preference rankings based on perceived pictorial effectiveness.

2.3. Materials

Sixteen pictorial concepts were examined. They are shown in Fig. 1 (in the over slash condition). Sets of laminated cards (12.7 cm × 12.7 cm) were produced, with each set consisting of a pictorial in the four circle-slash types and in the two orientations, for a total of eight cards per set. An example pictorial set in its eight variations (for NO TRUCKS) is shown in Fig. 2.

Pictorials were printed in black ink on a white background, with the circle and slash printed in safety red. As recommended in the ISO 3864 (1984) standard, the area of red included in the warning was 35% of the total area inside the outer rim of the circle, leaving 65% of the area for the pictorial. All pictorials were fully contained within a red circle with an outer diameter of 11.3 cm and a slash width of 1 cm. In accordance with ANSI Z535.2 (1991) and ISO 3864 (1984), the slash was maintained in a fixed position at a 45° diagonal from the top left to the bottom right aspect of the circle.

Four slash conditions were tested: slash over (in front of) the pictorial, slash under (behind) the pictorial, a partial (broken) slash, and a translucent slash revealing the image beneath. In the over slash condition, the slash was opaque where it crossed over the pictorial obscuring part of the image. In the under slash condition, the pictorial on top of the slash was opaque and the pictorial obscured part of the slash. In the partial slash condition, the slash was displayed as short, truncated "stubs" that terminated before crossing the pictorial, leaving a small amount of white space between the stub and the pictorial. 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 section of the slash.

Fig. 1. The 16 pictorials in the over slash condition.

Pictorials were grouped by their approximate direction of orientation. Orientation I generally included objects facing or turned to the left. Orientation II had objects faced or turned to the right. The criteria used to determine orientation were: (a) likely directional movement of the depicted object(s) and (b) relative amount of ink and physical mass of objects on the left and right sides of the pictorial.

Fig. 2. Example NO TRUCKS Pictorial in the 8 slash type variations (over, under, partial and translucent) and orientation (I = left versus II = right).

2.4. Procedure

Participants were told that the study was an investigation of individuals' judgments about pictures. The instructions emphasized that evaluations of each picture should consider potential environmental viewing conditions like rain, fog, or time of day in which those pictorials might be seen. They were also told that some people may have trouble seeing or comprehending picture details because of poor vision or cultural differences. Participants were given the cards in sets consisting of the eight versions of the same pictorial concept, and asked to lay them out on the table in an order based on how effectively each conveyed the intended message. Each participant arranged the cards from worst to best in a left to right direction. After the participant finished each set, the experimenter removed the cards and recorded the order. This procedure was continued until all 16 sets were ranked. The presentation order for sets and the cards within each set was randomized for each participant.

3. Results

The cell means for all conditions are shown in Table 1. The data are ranks, thus lower scores indicate greater preference. A 16 (pictorial) × 2 (orientation: I vs. II) × 4 (slash type: over, under, partial, or translucent) repeated-measures analysis of variance (ANOVA) was applied to these data. There was no main effect of pictorial, $F(15, 885) = 0.00$, $p = 1.0$, because all sets contained the same number of conditions to be ranked and consequently the means always produced the same value (i.e., 4.5). The ANOVA showed a significant main effect of orientation, $F(1, 59) = 9.39$, $p < 0.01$. In general, left facing versions of the pictorials were preferred ($M = 4.43$) over right-facing ones ($M = 4.57$).

The ANOVA additionally showed a significant pictorial × orientation interaction, $F(15, 885) = 10.12$, $p < 0.0001$. Simple effects analysis of this interaction showed that eight pictorials produced significant orientation differences ($p < 0.05$). Table 2 shows the means and the preferred orientation of these pictorials.

The ANOVA showed a significant main effect for slash-type, $F(3, 177) = 101.68$, $p < 0.0001$. Comparisons among the means using the Tukey's Honestly Significant Difference (HSD) test showed that the over ($M = 3.02$) and under ($M = 3.46$) slash versions did not significantly differ, but both were preferred compared to the partial ($M = 6.79$) and translucent ($M = 4.72$) slash versions ($ps < 0.05$). The translucent slash was significantly preferred compared to the partial slash ($p < 0.05$).

There was also a significant pictorial X slash-type interaction, $F(45, 2655) = 6.51$, $p < 0.0001$.

Table 1
Mean ranks as a function of pictorial, orientation (I = left versus II = right) and slash type (over, under, partial, and translucent)

		Slash type			
Pictorial	Orientation	Over	Under	Partial	Translucent
No Left/Right Turn	I	2.63	3.45	4.73	6.92
	II	2.40	3.78	5.10	6.98
No Flames	I	2.10	3.25	4.40	6.55
	II	3.30	4.12	5.10	7.18
Don't Drink Water	I	2.95	3.43	4.43	6.07
	II	3.55	3.78	4.73	7.05
No Smoking,	I	4.30	3.12	4.73	6.90
Eating or Drinking	II	2.33	3.13	4.60	6.88
No Entrance	I	2.95	3.57	4.77	6.90
	II	2.72	3.48	4.70	6.92
Do Not Touch	I	4.13	3.17	4.65	6.38
Exposed Gears	II	3.83	2.83	4.68	6.32
No Bicycling	I	3.05	3.28	4.73	6.97
	II	3.10	3.22	4.63	7.02
No Snowmobiling	I	2.80	3.42	5.10	6.85
	II	2.72	3.30	4.93	6.88
No Trucks	I	2.08	3.88	4.98	6.87
	II	2.27	3.77	4.98	7.17
No Dogs	I	2.97	4.00	5.28	7.05
	II	2.07	3.50	4.60	6.53
No Exit	I	2.55	4.55	4.37	6.73
	II	2.20	4.45	4.45	6.70
Do Not Touch	I	2.67	3.58	4.72	6.98
Switch	II	2.83	3.47	4.78	6.97
Do Not Dig	I	2.73	2.92	4.55	6.25
	II	3.93	3.57	5.08	6.97
No Diving	I	2.58	2.98	4.48	6.70
	II	3.83	3.47	5.13	6.82
Do Not Climb	I	3.25	3.02	4.47	6.82
Tower	II	3.67	3.17	4.78	6.83
Keep Out	I	3.68	2.78	4.10	6.57
High Voltage	II	4.53	3.30	4.32	6.72

Table 2
Mean preference ranks of pictorials with significant orientation differences

Pictorial	Preferred	Orientation	
		Left (I)	Right (II)
No Flame	I	4.08	4.93
Don't Drink the Water	I	4.22	4.78
No Smoking, Eating, or Drinking	II	4.76	4.24
No Dogs	II	4.83	4.18
No Digging	I	4.11	4.89
No Diving	I	4.19	4.81
Do not Climb Tower	I	4.39	4.61
Keep Out, High Voltage	II	4.28	4.72

The partial slash was consistently the least preferred slash type across all pictorials. The translucent slash was consistently preferred compared to the partial slash and consistently less preferred compared to the over and under slashes. However, there were two exceptions to this pattern for the translucent condition. Tukey's HSD test showed no significant difference between the translucent slash and: (a) the under slash for the NO EXIT pictorial, and (b) the over slash for the KEEP OUT – HIGH VOLTAGE pictorial.

Additional comparisons using the Tukey's HSD test showed that the over slash was significantly preferred to the under slash for the following six pictorials ($ps < 0.05$): NO TURN ($M = 2.52$ vs. 3.61), NO FLAMES ($M = 2.70$ vs. 3.68), NO TRUCKS ($M = 2.18$ vs. 3.83), NO DOGS ($M = 2.52$ vs. 3.75), NO EXIT ($M = 2.38$ vs. 4.50), and DO NOT TOUCH SWITCH ($M = 2.75$ vs. 3.53). The under slash was significantly preferred compared to the over slash for two pictorials ($ps < 0.05$): DO NOT TOUCH EXPOSED GEARS ($M = 3.00$ vs. 3.98), and KEEP OUT – HIGH VOLTAGE ($M = 3.04$ vs. 4.11). No other pictorials showed a significant difference between the over and under slashes.

Finally, there was also a significant three-way pictorial × orientation × slash type interaction, $F(45, 2655) = 4.69$, $p < 0.0001$. The means indicated that this interaction reflected the following: For several nonsymmetrical pictorials, some orientations were less preferred due to the slash's intersection (overlap) with its critical features making them less apparent. This effect was largest for the over slash compared to the other slash types (as this slash type completely obscures the underlying features). The following pictorials showed this pattern: NO FLAMES; DON'T DRINK THE WATER; NO SMOKING, EATING OR DRINKING; DO NOT DIG; NO DIVING; and KEEP OUT – HIGH VOLTAGE. Examples of obscured pictorials in the over condition are shown in Fig. 3.

4. Discussion

In general, the over and under slash types were the most preferred prohibitive symbols. The translucent slash was the next most preferred, and the least preferred was the partial slash. Thus, the pattern of results fails to support the idea that the over and under slash might be least preferred. There are at least two possible explanations for these findings. First, familiarity could have influenced participants' preferences. Prohibitive pictorials commonly use the over and the under slash (although the latter less commonly) and as a consequence people may prefer these slash types simply because they are familiar. Second, their preference could be partly due to Gestalt principles. In the over and under conditions, there was a complete form – either the

Fig. 3. Examples of obscured pictorials in over slash condition.

slash or the pictorial. The other two slash types had more separate or "broken" parts.

The results also do not support the prediction that participants would most prefer the translucent slash, the variant introduced in this study. There are at least three reasons why this slash version did not perform as well as expected. First, this variant was unfamiliar which might have negatively affected preference judgments. Second, the translucent slash had reduced contrast where the color of the slash changed to gray when it crossed the pictorial. This reduced this area's legibility which may have contributed to the lower evaluations. Third, observers might view the section with the color change as a separate, distinct part rather than perceiving the whole pictorial and slash as a unit, and this too might have had a negative effect on the evaluations.

The partial slash received the worst scores probably because the slash itself was the least noticeable. The size of the two stub parts varied as a function of the pictorial dimensions and features. For some pictorials, the stubs of the partial slash were shorter and less apparent than for other pictorials. The evaluations of the partial slash might have been better had the stub tip edges reflected the pictorial's adjacent contours rather than having a constant shape as in this study.

The failure to find positive results for the partial slash is contrary to Dewar's (Dewar, 1976) glance legibility findings. In that study, recognition performance was highest for the no slash and the partial slash conditions compared to the over slash. However, Dewar (1976) used a different methodology assessing recognition under very fast exposure conditions and had participants respond by matching to a set of available referent verbal labels. The highly dissimilar methodologies could be responsible for the inconsistent findings between the present study and Dewar's.

While the over and under slash were generally the most preferred methods of conveying prohibition, there were some exceptions to this pattern. In certain cases, pictorials in a particular orientation and slash type produced significantly lower effectiveness judgments. These exceptions occurred primarily when critical pictorial details were obscured by the slash. This effect was more evident with the over slash than with the other slash types. Apparently, participants believed that concealing important features would negatively affect pictorial interpretability, and hence effectiveness.

The rankings provided by participants provide insight into some of the potential issues that may arise as people attempt to understand pictorials obscured by the prohibitive slash. A lowered level of perceived effectiveness could indicate ambiguity, confusability or complexity.

Ambiguity refers to a warning in which the over slash obscures some detailed aspect of the pictorial such that it has multiple meanings. The pictorial presented in the left side of Fig. 4 is an actual pictorial used in an automatic door warning. It is an ambiguous pictorial in which the slash hides a critical portion of the person as depicted. While the warning is supposed to mean NO STANDING, it also could be misinterpreted as NO WALKING.

Confusability refers to a situation in which a pictorial is not understandable due to the presence of unfamiliar or unusual features. The pictorial presented in Fig. 5 could lead to such a state of confusion. It is a combination of two fairly common traffic signs (NO LEFT TURN and NO U TURN) to form a single NO LEFT OR U TURN sign (Gattis, 1987). While each of the prohibitive messages contained in this warning may be easily recognized in isolation, they may not be quite as apparent when presented together. The placement of the over slash makes the pictorial too complex and fails to clearly indicate the prohibition. In the case of the warning shown in Fig. 5, the slash is not placed symmetrically across both parts of the pictorial. Hence, the "left turn" aspect of the warning is mostly missed by the slash, confusing the intended message.

Complexity refers to the presentation of pictorials that seem to conflict with a prohibition message by presenting the negative consequences of an action. As an example, the DO NOT TOUCH EXPOSED GEARS pictorial (sixth from the top in the first column of Fig. 1) depicts a crushed hand within gears to communicate the consequences of contacting industrial machinery. Pictorials such as these are complex in the sense that they may be presented without any prohibitive circle-slash and still convey the intended meaning. Warnings of this

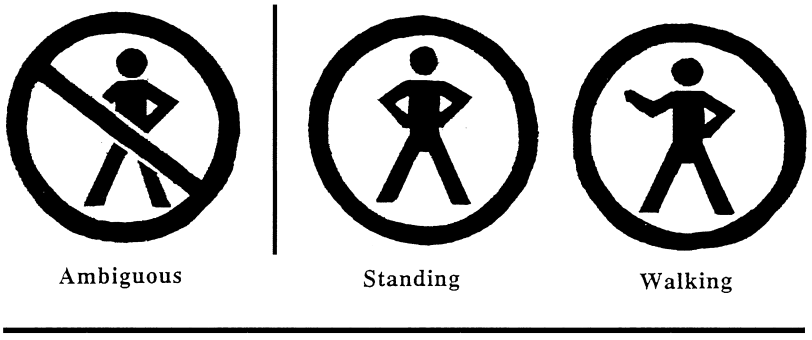

Fig. 4. Ambiguous pictorial with circle slash overlay that hides relevant details; the two pictorials on the right are the possible interpretations.

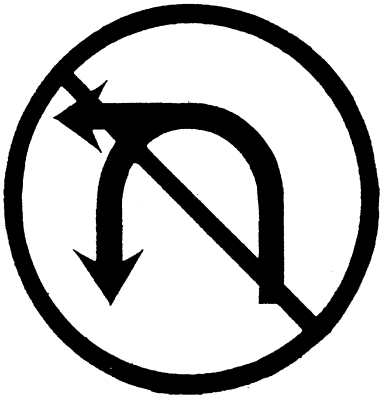

Fig. 5. An example of a complex prohibitive pictorial.

type are actually "double negatives," but probably very few people would interpret them as positive messages. The DO NOT TOUCH EXPOSED GEARS negation pictorial is actually a combination of two concepts: (1) the prohibition of a precursor behavior, i.e., getting hands near the gears, and (2) the consequences of doing so. Further investigations are necessary to determine whether one or both concepts separately or combined are perceived as differentially effective.

The present data suggest that careful consideration of the pictorial's placement with respect to the slash is important. In some cases, the problem of concealment can be addressed by altering the orientation of the pictorial. In other cases, however, the concept might have to be represented by a different or modified pictorial so that all important features are visible.

Acknowledgements

The authors wish to thank Blair M. Brewster and Electromark Co. for financial support and the production of materials used in this study. Portions of this article were presented at the 40th Annual Meeting of the Human Factors and Ergonomics Society in Philadelphia, Pennsylvania (Glover et al., 1996). Requests for reprints should be sent to: Michael S. Wogalter, Department of Psychology, 640 Poe Hall, North Carolina State University, Raleigh, NC 27695-7801 USA.

References

ANSI, 1991. American National Standard for Environmental and Facility Safety Signs: Z535.2. American National Standards Institute, Washington, DC.

Dewar, R.E., 1976. The slash obscures the symbol on prohibitive traffic signs. Human Factors 18, 253–258.

Ells, J.G., Dewar, R.E., 1979. Rapid comprehension of verbal and symbolic traffic sign messages. Human Factors 21, 161–168.

Gattis, J.L., 1987. Distinguishing between left turn and U-turn prohibitions. ITE-Journal 57, 4.

Glover, B.L., Magurno, A.B., Murray, L.A., Wogalter, M.S., 1996. Pictorial negations: preferences for different circle-slash variations. In: Proceedings of the Human Factors and

Ergonomics Society 40th Annual Meeting. Human Factors Society, Santa Monica, CA, pp. 910–914.
Gough, P.B., 1965. Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior 4, 107–111.
ISO, 1984. International Standard for Safety Colours and Safety Signs: ISO 3864. International Standards Organization, Switzerland.
Lanjunen, T., Hakkarainen, P., Summala, H., 1996. The ergonomics of road signs: explicit and embedded speed limits. Ergonomics 39, 1069–1083.
Sanders, M.S., McCormick, E.J., 1993. Human Factors in Engineering and Design. 7th ed., McGraw-Hill, New York.
Sekuler, R., Blake, R., 1985. Perception. Alfred A. Knopf, New York.