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Facilitating pictorial comprehension with color highlighting

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ABSTRACT

Pictorials can aid in communicating warning information, but viewers may not always correctly comprehend them. Two experiments focused on whether the use of relevant highlighting could benefit pictorial comprehension. A set of warning-related pictorials were manipulated according to three-color highlighting conditions: highlighting areas more relevant to correct comprehension, highlighting areas less relevant to comprehension, and no highlighting. Participants were asked to describe the purpose and meaning of each pictorial presented to them. The findings from both experiments indicate that comprehension of warning pictorials is higher for the relevant highlighting condition than the other two conditions. The highlighting of less relevant areas reduced comprehension compared to no highlighting. Use of appropriately placed highlighting could benefit the design of a complex symbol by pointing out pertinent areas to aid in determining its intended conceptual meaning.

1. Introduction

Understanding safety information concerns, products, and equipment is important for their proper use (Wogalter, 2006). Communicating safety information has become increasingly challenging as people speaking different languages intermix through travel and trade. Illiteracy can increase this challenge. To overcome these and related difficulties, symbols offer a potential way to address the language barrier as a sort of "universal" language. However, a common finding in research on symbol comprehension is that the intended communication may not be understood properly (e.g., Hancock et al., 1999). Worse yet, some symbols in certain contexts can confuse the viewer by conveying the wrong information (e.g., Zwaga and Boersema, 1983). Nevertheless effective symbols seem to offer benefits. In addition, symbols appear to be useful in attracting attention, which is important to processing safety communications (Bzostek and Wogalter, 1999; Laughery et al., 1993).

Because of difficulties in understanding symbols, domestic and international standards organizations have produced methods and criteria to assess comprehension adequacy of symbols. The American National Standard Institute's (ANSI) Criteria for Safety Symbols requires 85 percent correct in a comprehension test with a sample of 50 people reporting the intended concept. Criteria include that no more than five percent of the sample may experience critical confusion (an opposite or very wrong response; ANSI Z535.3, 2011). The International Organization for Standardization (ISO) also has a set of guidelines for symbol comprehension (ISO 9186, 2007). ISO and ANSI are in the process of harmonizing their symbol guidelines.

Designing symbols that meet ANSI criteria is reportedly difficult (e.g., Davies et al., 1998; Hancock et al., 2004; Zwaga and Boersema, 1983). To aid designers in creating symbols that meet these criteria, the human factors literature offers strategies and methods to increase comprehension (e.g., Collins and Lerner, 1982; Easterby and Hakiel, 1981; Hancock et al., 2004; Wogalter et al., 2006). For example, one strategy to influence symbol comprehension is to enhance legibility — the visual clarity of a symbol (Wogalter et al., 2002). Traditionally, symbol simplicity is preferred to enhance legibility (Wogalter et al., 2006) resulting in the use of bold lines in lieu of fine lines or details.

Some guidelines (e.g., FMC, 1985; Westinghouse Electric Corporation, 1981) and standards (e.g., ANSI Z535.3, 2011; ISO 3864-1, 2003) suggest the use of simple symbols for warnings. However, these suggestions may be inappropriate in situations necessitating specific and complex communication of information. When symbols lose increasingly more information due to simplification, the symbol may lack the necessary information for individuals to interpret its intended meaning. Fig. 1 provides an example of a symbol that appears to lack enough information to attain a high level of comprehension. So sometimes introducing increased information or detail may benefit symbols, which is contrary to conventional design strategies emphasizing minimal detail. Detail may be necessary for some symbols to meet high levels of comprehension. The additional information may aid the

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Fig. 1. Symbol of a dam.

viewer in comprehending situational considerations, avoidance strategies, and consequences related to the symbol. Fig. 1 would likely be benefitted by at least some additional information within the symbol, such as more specifics about the dam and surrounding environment or a different perspective of the structure. One of the main reasons that guidelines on warnings mandate limited detail is that lesser important information (e.g., detail) may capture and hold attention to the detriment of attention to relevant details and the determination of the symbol's intended meaning (Wogalter et al., 2006). Symbols designed with minimal complexity are differentiated from pictorials, which are symbols designed with greater amounts of detail and information. Pictorials might benefit from prominent aspects or characteristics that direct the viewer's attention to the most relevant information.

Salience is a stimulus-driven or bottom–up process whereby physical characteristics tend to "pop-out" from the context and seemingly to stand out effortlessly (Fecteau and Munoz, 2006; Yantis, 2000). The addition of color is one method to increase salience (e.g., Itti et al., 1998; Peters et al., 2005). Colored backgrounds are commonly used in warning pictorials to attract viewer's attention from environmental stimuli to the warning (ISO 3864-1, 2003). Highlighting a limited area of the pictorial with color could be used to increase the salience of the most relevant details of the pictorial. Focusing attention through highlighting could reduce the potential adverse effects of introducing greater pictorial complexity.

The use of highlighting to direct viewer's attention has been demonstrated in previous research in other areas. For example, Wickens et al. (2004) investigated the utility of varying intensity of highlighting in the performance of map reading tasks by increasing the salience and discriminability of stimuli. Martin et al. (1987) found that highlighting can increase performance of visual search with minimal performance cost to ignoring incorrectly highlighted stimuli. Wu and Yuan (2003) demonstrated the superiority in reading times of traditional, color highlighting in comparison to no highlighting, and other, non-traditional forms of highlighting (e.g., flashing text). In a review of color coding research, Christ (1975) concluded that color facilitates identification and searching of objects, particularly when the color is known to be uniquely associated with the target.

Potential harmful effects of highlighting have also been observed (e.g., Fisher and Tan, 1989; Tamborelloii and Byrne, 2007). In visual search tasks, when highlighting is placed over the target stimuli, search time decreases. However, when highlighting is placed over a distracter, search time increases. Whether highlighting is placed over the target or a distracter, it is drawing the viewer's attention toward that area. Additionally, inappropriate highlighting has been shown to interfere with text comprehension when placed on less relevant or irrelevant information (e.g., Gier et al., 2009). The harmful effects of color were also identified by Christ's (1975) review. For example, when color is added to distracters, the accuracy of identifying features of targets without color decreases.

Two experiments described in this report examine whether color highlighting can improve pictorial comprehension performance. Two highlighting conditions are examined: relevant and irrelevant. In the relevant highlighting condition, a portion highly pertinent or relevant to the intended meaning of the pictorial is overlaid with the color yellow. It was expected that highlighting would enhance pictorial comprehension compared to the same pictorials with no highlighting. This enhancement could be explained by the highlighting focusing viewers' attention to pertinent aspects of the pictorial compared to the absence of relevant highlighting. In the irrelevant condition, a portion minimally pertinent or relevant to the intended meaning of the pictorial is overlaid with the color yellow. It was expected that this highlighting would diminish pictorial comprehension compared to the same pictorials with no highlighting. This diminishment in performance could be explained by the highlighting focusing viewer's attention away from pertinent aspects of the pictorial compared to the absence of irrelevant highlighting. Irrelevant highlighting may misguide viewers' attention resulting in lower comprehension. The second experiment differed from the first by sampling from a different population and addressing methodological issues.

2. Experiment 1

Pictorial comprehension is investigated comparing relevant and irrelevant highlighting to no highlighting.

2.1. Method

2.1.1. Participants

Eighty-four North Carolina State University undergraduate students (mean age = 18.7 years, SD = 1.2) participated as part of a course requirement for an introductory psychology course. The sample was comprised of 35 males and 49 females.

2.1.2. Experimental design and stimuli

Participants completed an online questionnaire with 13 pictorials. Each pictorial was accompanied with a short statement briefly describing the context where it might be located. Three of the pictorials were specious and intended to help disguise the purpose of the study. Responses to the specious pictorials were not analyzed. The other 10 pictorials were experimentally manipulated to form three conditions. The three experimental conditions were no highlighting, less relevant (or irrelevant) highlighting and relevant highlighting. To form these conditions, a set of "base" pictorials was first produced. All of these had no highlighting and served as stimuli in the no highlighting condition. From the base non-highlighted pictorials the other two experimental conditions were produced. To form the relevant highlighting set of pictorials yellow was added that encircled and covered the most pertinent portion(s) of the pictorial in order to determine its meaning. This area was generally the focal point of the interaction between the human figure and the instructed action. The less relevant (irrelevant) highlighting added color to the base pictorials that did not cover the focal point of the interaction between the human figure and the instructed action. This area included any distinct object within the pictorial that did not overlap with the relevant highlighting portion. For examples, see Figs. 3 and 4 shown later in this article. Highlighting was always accomplished using a highly saturated yellow hue. (Note: the pictorials shown in the figures as illustrative examples use gray highlighting in lieu of yellow.)

The specific conceptual meanings (referents) of the ten manipulated pictorials were: (1) hold on with your hand to ladder while