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Comprehension of hazard communication: Effects of pictograms on safety data sheets and labels

Eric Boelhouwer [a,*], Jerry Davis [a], Ana Franco-Watkins [b], Nathan Dorris [a], Claudiu Lungu [c]

[a] Department of Industrial and Systems Engineering, 3301 Shelby Center, Auburn University, AL 36849, United States
[b] Department of Psychology, 226 Thach Hall, Auburn University, AL 36849, United States
[c] Department of Environmental Health Science, University of Alabama at Birmingham, Ryals Public Health Building 520B, 1530 3rd Ave S, Birmingham, AL 35294, United States

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ABSTRACT

Introduction: The United Nations has proposed the Globally Harmonized System (GHS) of Classification and Labelling of Chemicals to make hazard communication more uniform and to improve comprehension. *Method:* Two experiments were conducted to test whether the addition of hazard and precautionary pictograms to safety data sheets and product labels would improve the transfer of information to users compared to safety data sheets and product labels containing text only. Additionally, naïve users, workers, and experts were tested to determine any potential differences among users. *Results:* The effect of adding pictograms to safety data sheets and labels was statistically significant for some conditions, but was not significant across all conditions. One benefit of the addition of pictograms was that the time to respond to the survey questions decreased when the pictograms were present for both the SDS and the labels. GHS format SDS and labels do provide benefits to users, but the system will need further enhancements and modifications to continue to improve the effectiveness of hazard communication. *Impact on industry:* The final rule to modify the HCS to include the Globally Harmonized System (GHS) for the Classification and Labelling of Chemicals announced by OSHA (2012b) will change the information content of every chemical SDS and label used in commerce. This study suggests that the inclusion of GHS hazard pictograms and precautionary pictograms to SDS and labels may benefit the user.

1. Introduction

The Occupational Safety and Health Administration (OSHA) issued a final rule in 2012 to modify the Hazard Communications Standard (HCS; OSHA, 1994) to conform to the United Nations Globally Harmonized System (GHS) of Classification and Labelling of Chemicals. By modifying the HCS, OSHA will require changes to the information content of material safety data sheets (MSDS) and product labels. Using GHS terminology, MSDS documents are known as safety data sheets (SDS) and this term is used in this paper. OSHA stated in the final rule these modifications of the Hazard Communications Standard (HCS) (OSHA, 1994) will improve "the quality and consistency of information provided to employers and employees regarding chemical hazards and associated protective measures" (OSHA, 2012b). OSHA (2006) has also estimated there are over 945,000 hazardous chemical products in the workplace. The HCS (OSHA, 1994) is routinely one of the most commonly cited standards, including 2011 when it was the third most cited standard by OSHA (2012a). The goal of this study is to evaluate if there is a difference in comprehension of the information presented in a SDS or a product label if GHS hazard pictograms and European Union precautionary pictograms were present. It should be noted that the third revised edition of the GHS was used by OSHA to modify the HCS and this edition did not specify the use of precautionary pictograms on SDS. However, examples of precautionary pictograms are provided in Annex 3 Section 4 of the GHS from both the European Union (1992) and the South African Bureau of Standards (1999). Also, the precautionary statements in the third revised edition of the GHS (United Nations, 2009a) had not been agreed upon and harmonized by the United Nations at the time of this study.

Pictograms are often used in many types of technical documents (including owner's manuals and on-product labels) to help convey safety information. It has not been common practice in the United States to include additional pictograms on SDS or product labels beyond those required for transportation, even though the HCS is a performance-based standard and does not provide detailed guidance with regard to pictogram use. This paper will present the findings from two surveys: one for SDS and the other for product labels. In the first survey, participants referenced SDSs with and without pictograms to respond to items related to information provided on the

* Corresponding author. Tel.: +1 504 606 9460; fax: +1 334 844 1381.
E-mail addresses: boelhej@auburn.edu (E. Boelhouwer), davisga@auburn.edu (J. Davis), amf0001@auburn.edu (A. Franco-Watkins), dorrint@auburn.edu (N. Dorris), clungu@ms.soph.uab.edu (C. Lungu).

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SDS. In the second survey, participants responded to items about the information provided on product labels, both with and without GHS hazard and EU precautionary pictograms.

2. Prior research

The studies that have attempted to measure comprehensibility of chemical hazard communications have found that the level of comprehension of SDS is relatively low (Kolp, Sattler, Blayney, & Sherwood, 1993; Phillips et al., 1999; Sadhra, Petts, McAlpine, Pattison, & MacRae, 2002; Seki et al., 2001). Researchers have used a variety of approaches to evaluate risk, format, and comprehension. Studies using written surveys and allowing the participants to refer to the SDS to answer questions, have indicated that participants respond correctly to 64–71% of the items (Kolp et al., 1993; Phillips et al., 1999). However, none of the studies evaluated GHS format SDS or attempted to show differences between user groups. Kolp et al. (1993) evaluated the use of the OSHA Form 174 and the International Chemical Safety Card (ICSC) and found a higher average score for the ICSC format compared to the average score for the OSHA Form 174, but did not report the results of any statistical tests at the request of OSHA (Phillips et al., 1999). Phillips et al. (1999) attempted to quantify how well information was transferred to workers using three different formats: OSHA Form 174, ANSI Z400.1-1998, and the ICSC. From their survey and testing results, it was estimated that one third of the information was not absorbed in a sample of 160 workers. The rank order of the three formats, from the highest to the lowest, was the ICSC, followed by the OSHA Form 174, and then ANSI Z400.1-1998. This study reported no significant differences in the scores for the three formats, but did report significant differences for how well each format answered specific test questions.

Additional studies have evaluated users' comprehension of the information presented in a SDS. Niewohner, Cox, Gerrard, and Pidgeon (2004) used surveys, semi-structured interviews, and focus groups to investigate comprehension of hazard communication methods in the United Kingdom for small businesses (less than 25 employees). The study suggested that generic chemical information is of little relevance to most users. Niewohner et al. stated that workers relate to a given chemical through particular working practices and exposure patterns which they shape their attitudes toward the potential risks inherent to the chemical.

These results are supported in part by a prior study focusing on smaller firms by Sadhra et al. (2002) that investigated the comprehension of workers in the electroplating industry. The workers learned most common practices from fellow workers and understood the acute risks of the chemical based on personal experience. The authors reported the workers did not fully understand the potential long-term effects of the chemicals utilized in their everyday work environment. Interestingly, ninety-two percent of the experts thought the SDS were too complex for the platers, while only 32% of the platers believed this to be the case (Sadhra et al., 2002).

Other studies have focused on information presented in SDS or the order in which the information is presented. Before the enforcement of hazard communication in Japan in 2000, Seki et al. (2001) sent surveys to 422 workplaces (i.e., users not producers) of chemical products to evaluate the comprehension of eight terms commonly used on SDS: Chemical Abstract Service (CAS) number, occupational exposure limit, administrative level, acute toxicity, mutagenicity, carcinogenicity, sensitization, and gas mask for organic compounds. Responses were categorized by the relative size of the employment firm (small, medium, and large). The SDS was considered unsatisfactory by 52.8% of the small and 50.8% of the medium firm employees because the words and/or content were difficult to understand as compared to 25% for large firms. However, understanding of the terms gas mask for organic compounds, carcinogenicity, and occupational exposure limit occurred for 90% of the respondents whereas the terms mutagenicity, sensitization, and CAS number were understood by less than half of the respondents.

OSHA's modifications to the final rule for the HCS will also change the order in which the sections are presented, which was supported in part by Smith-Jackson and Wogalter (1998) and investigated the order of the SDS sections. These same authors extended this research and used a mental model approach to look at naïve users (i.e., college students), homemakers, and firefighters to determine a preferred order for SDS sections for these groups (Smith-Jackson & Wogalter, 2007). Subjects exhibited a preference for the health effect data to be of greatest priority and therefore should be placed more prominently on SDS. This preference was incorporated by OSHA into the revised HCS final rule.

Another component of hazard communication is the on-product label and once the revised HCS is fully implemented, the information content of the labels will also change. Previous research suggests that warnings must be understood to be effective (Dorris & Purswell, 1978). The authors also suggest that graphic representations, or pictograms, may be recognized more quickly and have more intrinsic interest than written warnings (Dorris & Purswell, 1978). O'Conner and Lirtzman (1984) suggest that a higher number of hazard statements on a chemical label increase the amount of time to respond to a question about a particular item on the label. Rhoades, Frantz, and Miller (1990) further support this finding that overly detailed warnings may overload the user. Robinett and Hughes (1984) suggest that the use of pictograms without text may be preferable. However, Young and Wogalter (1990) found that pairing pictograms with written warnings may associate the two in memory and this may cue the warning message and facilitate the retrieval of the hazard information in the written warning on re-exposure to the pictogram. In a study by Friedmann (1988), the effect of adding pictogram warnings to a written warning was not shown to increase compliance, but there was an effect between the perceived hazard of the product and reading, following, and recalling the warning. Lehto (1998) found that if the information to respond to the question was available on the label, as opposed to only in the SDS, then the speed and accuracy of the participants increased significantly and the label format did not strongly impact performance.

Research regarding the use of pictograms for hazard communication suggests that users may not understand the intended meaning of pictograms (Hara et al., 2007; Rother, 2008; Wilkinson, Cary, Barr, & Reynolds, 1997). The study by Hara et al. (2007) found that participants in Japan had difficulty comprehending the GHS pictograms for gas cylinder, corrosion, health hazard, and environment with no accompanying textual statements. Wilkinson et al. (1997) reported that pesticide users found it significantly easier to obtain information from labels with pictograms added than from labels containing text only. Both Wilkinson et al. (1997) and Rother (2008) used the United Nations Food and Agricultural Organization pictograms for pesticide risk communication that are included in the GHS (United Nations, 2009a) as examples of precautionary pictograms and are in the South African standard titled “The Classification and Labelling of Dangerous Substances and Preparations for Sale and Handling” (South African Bureau of Standards, 1999). The findings for both studies suggest that pictograms by themselves may not communicate the intended meaning to participants. Rother (2008) suggests that these findings challenge the viability of the GHS pictograms that were not piloted prior to the adoption of the system and are used to represent complex risk assessment data. Many of the symbols for the GHS are the same as used for transportation warnings and are included in the Recommendations on the Transport of Dangerous Goods, Model Regulations (United Nations, 2009b). The flame, exploding bomb, and skull and crossbones symbols (see Fig. 1) were originally developed by the International Labor Organization (ILO). The ILO had established a chemical committee to create a plan for chemicals to be labeled uniformly throughout the world and the work of this committee also proposed the use of symbols for different hazard classes in 1955 (Mellan & Mellan, 1961). The two symbols not used by