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

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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

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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

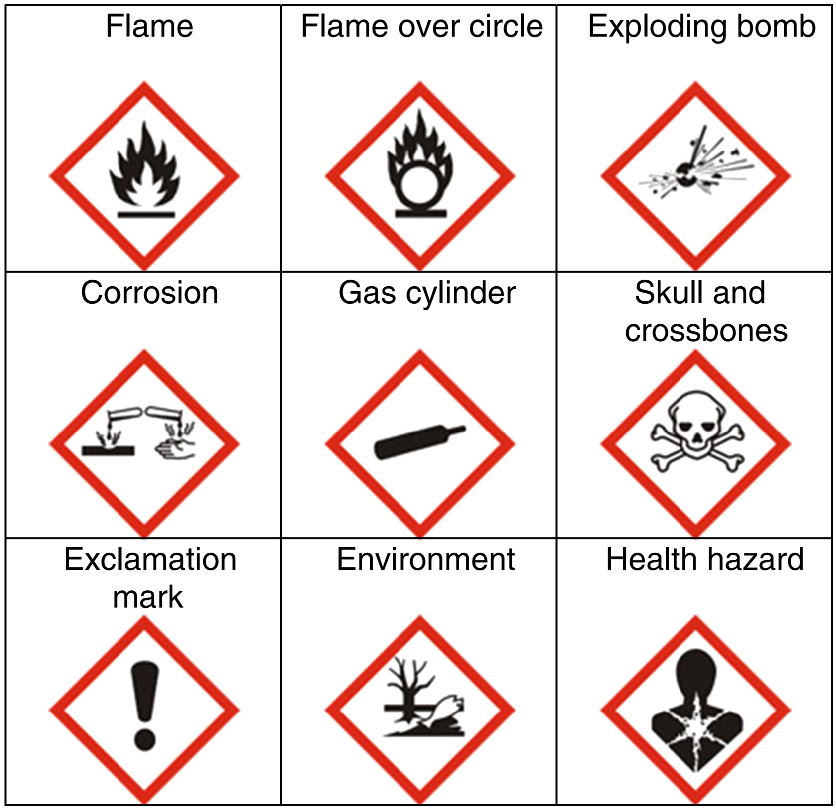

Fig. 1. Examples of the GHS hazard pictograms (United Nations, 2009a).

transportation sector are the health hazard and the exclamation mark (see Fig. 1). Both of these were created as part of the development work for the GHS.

Research by Slovic, Fischhoff, and Lichtenstein (1980) on the concept of risk suggests that people's perceptions are determined by a combination of severity and likelihood information. Previous research on warning labels has attempted to address user's perception of risk, which can be considered a function of severity and likelihood. Otsubo (1988) found no significant effect for the type of warning label (words only, pictogram only, or words and pictogram), with no significant effect whether participants noticed, comprehended, or remembered the warning. But pictograms should increase individual's awareness of risk, by providing an "instantaneous memorandum" of a risk (Otsubo, 1988). Wogalter, Young, Brelsford, and Barlow (1999) have shown that high severity warnings produced higher hazard ratings. Wogalter and Barlow (1990) suggest that the injury severity on a warning label influences user ratings of hazard, but has no effect for the perceived likelihood of an injury. Friedmann (1988) found that participants perceived products containing both a written warning and a symbol to be more dangerous than products containing only a written warning. This is in contrast to the finding by Wilkinson et al. (1997) that the addition of pictograms did not have a significant effect on perceptions of how dangerous the herbicide was to the user. O'Conner and Lirtzman (1984) found an increase in the average rating of chemical hazard corresponding to the number of hazards on the label.

In a review of the available literature at the time, DeJoy (1989) concluded that previous studies of safety warnings have evaluated comprehension and not compliance, tested user populations which are not typical, and use overly simplistic warnings. The present surveys attempt to address these limitations by assessing how the presence of hazard and precautionary pictograms influences the speed and accuracy of reading realistic GHS product labels. Participants' comprehension was evaluated because it is the most important factor of communication in attempting to evaluate the new GHS formats for SDS and labels. The user populations tested in this study should represent a range of user populations from naïve users to experts.

3. Materials and methods for SDS survey

3.1. Subjects

Ninety ($n = 90$) Auburn University undergraduate students were recruited as participants from their psychology classes and are henceforth referred to as naïve users. Individuals whom by education, training, or work experience would have a high awareness of hazard communication and are members of selected professional societies: the Society for Chemical Hazard Communication (SCHC), the American Industrial Hygiene Association (AIHA), and the American Society of Safety Engineers (ASSE) are henceforth referred to as experts. Forty five ($n = 45$) experts were recruited via e-mail invitations distributed to the above mentioned professional societies. Demographic information was collected and participants responded to questions to establish their knowledge of hazard communication. Two naïve participant data were not used because they did not use the proper SDS for each section of the survey. For the remaining 88 naïve and 45 expert responses, there was no missing data. Participation was anonymous, with no direct identifiable information collected from any of the participants. All of the information collected was self-reported by the participants (Table 1).

3.2. Materials

3.2.1. Safety data sheets

Two versions, one with pictograms and one without, of a 16 section SDS were created for two chemicals. One version contained the GHS prescribed hazard and precautionary statements. The other version contained identical text with GHS hazard pictograms and precautionary pictograms added to the SDS. The name of each chemical was replaced with a fictitious name (i.e., Chemical A and Chemical B) to help prevent

Table 1
Participants' demographic profiles.

	N	Naïve users	Experts
Participants	133 (100%)	88 (67%)	45 (33%)
Gender			
Male	40 (30%)	22 (25%)	18 (40%)
Female	93 (70%)	66 (75%)	27 (60%)
Self rating of HAZCOM knowledge			
Below average	49 (44%)	59 (67%)	0 (0%)
Average	34 (26%)	28 (32%)	6 (13%)
Above average	41 (30%)	1 (1%)	39 (87%)

previous knowledge from biasing the responses to the questionnaire. The SDS for Chemical A had four different hazard pictograms and seven different precautionary pictograms. The SDS for Chemical B had six different hazard pictograms and seven different precautionary pictograms. Hazard pictograms were placed in Section 2 hazard identification and were 2 cm wide and 2 cm tall, similar to the pictograms shown in Fig. 1.

In the present survey used precautionary pictograms similar to those from the European Union (1992) to represent personal protective equipment. None of the precautionary pictograms in this study indicated a protective action that a user may use to avoid or reduce the potential harm from an exposure. Precautionary pictograms were placed in Section 8 exposure controls/personal protection immediately preceding the individual protection measures. The precautionary pictograms were 2 cm wide and 2 cm tall, similar to Fig. 2.

3.2.2. Survey instrument

The questionnaire covered the sections pertaining to hazard identification, first-aid measures, accidental release measures, handling and storage, exposure controls/personal protection, and toxicological information. Approximately 60% of the questions addressed the potential health effects and personal protection measures. An online survey tool (www.qualtrics.com) was used to administer the questionnaire via the internet to participants. Participants responded to nine yes/no questions about the SDS and the information to answer each question may or may not have been present in the SDS. Participants were also asked to report whether they referred to the SDS to answer the yes/no questions.

3.3. Procedure

The participants were presented with SDS for two different chemicals, responded to a questionnaire, and were allowed to reference the SDS to answer the questions. Access to both SDSs was made available as portable document files (pdf) in an e-mail message from the researchers. They were instructed to familiarize themselves with the first SDS and then respond to that questionnaire. Similar instructions were used for the second SDS. Participants had as much time as needed to become familiar with each SDS. Two trials were conducted for each participant: one with a SDS with hazard and PPE pictograms and one with a SDS without pictograms for the other chemical. Four hazard pictograms were present on the SDS for Chemical A: flame over circle, corrosion, skull and crossbones, and health hazard. Six hazard pictograms were present on the SDS for Chemical B: flame, corrosion, gas cylinder, health hazard, exclamation mark, and environment. The participants were randomly assigned to one of four treatments:

Treatment 1 — SDS A (no pictograms), SDS B (pictograms)
Treatment 2 — SDS A (pictograms), SDS B (no pictograms)
Treatment 3 — SDS B (pictograms), SDS A (no pictograms)
Treatment 4 — SDS B (no pictograms), SDS A (pictograms).

A panel of safety researchers ($n = 3$) determined the correct responses and created a strict criterion for evaluating the responses. The strict evaluation criteria were based on comparing the questionnaire responses to the information provided on the SDS similar to the approach of other studies reported in the literature (Kolp et al., 1993; Phillips et al., 1999).

Fig. 2. Example of a precautionary pictogram for individual protection measures. This pictogram represents a face shield (United Nations, 2009a).

4. Results and discussion for SDS survey

4.1. Ability of SDS to convey information

Overall participants correctly responded on average to 73% of the material on the survey. The naïve users correctly responded to 67% of the material whereas the experts correctly responded to 86% of the material, $t\ (253) = -12.53$, $p < .001$.[1] The correct response percentage for the naïve users is comparable to other questionnaires of this type reported in the literature for industrial workers (Kolp et al., 1993; Phillips et al., 1999). The higher correct response rate for experts suggests that their background and experience may play a role in their improved performance. There was also a significant effect for Chemical B when pictograms were present on the SDS, $t\ (113) = -3.79$, $p < .001$.[1] Because the presence of the pictograms was significant for one, but not both, of the chemicals further analysis was conducted to evaluate the effects of adding pictograms to improve the effectiveness of communicating safety information for questions related to three groupings: physical hazards, health effects, and personal protective equipment.

4.1.1. Physical hazards

Further analysis was conducted to determine if the presence of the hazard pictograms had an effect on increasing the percentage of correct responses for the related survey questions. This grouping included the survey items covered by pictograms related to physical hazards (flame, flame over circle, exploding bomb, corrosion, and gas cylinder). The results presented in Table 2 show that the presence of the hazard pictograms for both Chemical A and Chemical B was significant. This finding suggests that there are benefits of adding hazard pictograms to improve the effectiveness of communicating safety information. This effect may be in part due to the one-to-one correlation between physical hazards and pictograms related to those hazards. For example, if a material is flammable, it is assigned the flame pictogram. While the flame pictogram may be assigned to represent one or more of the following on the label: Flammable Gases (Category 1), Flammable Aerosols (Categories 1, 2), Flammable Liquids (Categories 1, 2, 3), Flammable Solids (Categories 1, 2), Self-Reactive Substances (Types B, C, D, E, F), Pyrophoric Liquids (Category 1), Pyrophoric Solids (Category 1), Self-Heating Substances and Mixtures (Categories 1, 2), Substances and Mixtures, which in contact with Water, Emit Flammable Gases (Categories 1, 2, 3), and Organic Peroxides (Types B, C, D, E, F). The gist of the flame pictogram is intended to communicate the material is flammable.

Also, Table 2 shows that the experts responded with a significantly higher percentage of correct responses in all comparisons for physical hazards for both chemicals and for both conditions as compared to naïve users. Other comparisons relating to the survey questions for physical hazards were not significant.

[1] The Satterthwaite correction was used because the homogeneity of variances was violated for this test thereby reducing the degrees of freedom in the test.

Table 2
t-Test results for physical hazards.

	Chemical A	Chemical B	Pictograms present	No pictograms present
Groups	−4.67 df = 131[a] $p < .001$	−5.48 df = 129[a] $p < .001$	−5.05 df = 115[a] $p < .001$	−6.14 df = 124[a] $p < .001$
Pictogram	−3.29 df = 131 $p = .0013$	−6.42 df = 116[a] $p < .001$	–	–

[a] Because some of tests violated the assumption of homogeneity of variances, the Satterthwaite correction was applied which reduces the degrees of freedom presented for each test.

4.1.2. Health effects

For potential health effect hazards, survey items pertaining to the pictograms for health hazard, exclamation mark, and skull and crossbones were selected to evaluate the effect of the presence of the pictograms. The presence of the pictograms did not have a significant effect on the percentage of correct responses by the participants. Similar to physical hazards, the experts responded with a higher percentage of correct responses in all comparisons for health effects presented in Table 3. The lack of a significant finding for the relationship between the presence of the pictograms related to health effects may be related to the polysemy of the pictograms within GHS. For example, the health hazard pictogram may represent one or more of the following on the label: Respiratory Sensitization (Category 1), Germ Cell Mutagenicity (Categories 1A, 1B, 2), Carcinogenicity (Categories 1A, 1B, 2), Toxic to Reproduction (Categories 1A, 1B, 2), Specific Target Organ Toxicity (Single Exposure) (Categories, 1, 2), Specific Target Organ Toxicity (Related Exposure) (Categories 1, 2), and Aspiration Hazard (Categories 1, 2). The gist of the health hazard pictogram may be to communicate potential health effects, and it represents a wide range of issues including carcinogenicity, mutagenicity, and reproductivity.

4.1.3. Precautionary pictograms

Seven different precautionary pictograms were present on the SDS for Chemical A: air purifying respirator, gloves, boots, goggles, face shield, apron, and full body suit. Seven different precautionary pictograms were present on the SDS for Chemical B: full face respirator, air purifying respirator, gloves, boots, goggles, face shield, and full body suit. Table 4 shows the results of the *t*-tests for the precautionary pictograms.

The participants responded with a significantly higher percentage of correct responses when the precautionary pictograms were present, $t\ (111) = -3.49$, $p < .001$.[1] The presence of the precautionary pictograms was significant for Chemical B, $t\ (110) = -2.50$, $p = .013$,[1] but not for Chemical A, $p > .05$. Again, experts responded with a significantly higher percentage of correct responses than the naïve users for the survey questions related to the precautionary pictograms as can be seen in Table 4. Other comparisons for the presence of the precautionary pictograms were not significant.

4.2. Response time to survey items

Initially, the response times for the individual questions from 132 participants were used for the two trials (n = 264) because time data were not recorded for one of the expert participants. There was a significant effect between the time to respond to the survey items between strata, $t\ (261) = -5.13$, $p < .001$,[1] with experts taking longer to respond than naïve users. There was not an overall effect for time to respond when pictograms were present on the SDS, $p = .15$.

In the survey, there were nine participant response time outliers (i.e., greater than 1.5 times the inter-quartile range). When the data were analyzed again, following the removal of these outliers, the significant effect between strata remained, $t\ (253) = -5.11$, $p < .001$, with experts taking longer to respond than naïve users. However, the absence or presence of pictograms had a significant effect on time to respond, $t\ (253) = 2.3$, $p = .022$, with participants responding in a shorter amount of time when pictograms were present. This finding suggests that participants are able to use the pictograms to locate information more quickly within the SDS.

Table 3
t-Test results for health effects.

	Chemical A	Chemical B	Pictograms present	No pictograms present
Strata	−8.49 df = 126[a] $p < .001$	−5.90 df = 131[a] $p < .001$	−6.02 df = 126[a] $p < .001$	−8.35 df = 130[a] $p < .001$

[a] Because some of tests violated the assumption of homogeneity of variances, the Satterthwaite correction was applied which reduces the degrees of freedom presented t for each test.

Table 4
t-Test results for precautionary pictograms.

	Chemical A	Chemical B	Pictograms present	No pictograms
Strata	−7.29 df = 131[a] $p < .001$	−6.04 df = 130[a] $p < .001$	−6.28 df = 131[a] $p < .001$	−6.90 df = 131[a] $p < .001$
Pictogram	0.88	−2.50 df = 110[a] $p = 0.013$	–	–
Chemical	–	–	−3.49 df = 111[a] $p < .001$	−0.05

[a] Because some of tests violated the assumption of homogeneity of variances, the Satterthwaite correction was applied which reduces the degrees of freedom presented t for each test.

4.3. Response to yes/no survey items

For the nine yes/no questions, participants were asked to report if they consulted the SDS to help answer the questions. Across all questions, participants provided the correct response to the yes/no questions 54% of the time and self-reported referring to the SDS to assist with answering the question 61% of the time. The latter results are comparable to the 64% reported by Lehto (1998) and all results are presented in Table 5. Some of the precautions in the text were not always represented by the pictograms. The χ^2 test of independence for the relationship between the correct response and referring to the SDS was not significant for three (i.e., mutagenicity, reproductivity, and storage of the material) of the nine survey questions. For the individual questions, another χ^2 test was used to test for the relationship between strata and the correct response was significant for each of the nine questions with the experts responding with the correct answer more frequently than the naïve users.

5. Materials and methods for label survey

Another survey was conducted to test whether the addition of hazard and precautionary pictograms to product labels would improve the transfer of information to users compared to product labels containing text only. This survey tested to determine any potential differences among three user groups: naïve users, workers, and experts.

5.1. Subjects

Fifty five (n = 55) naïve users (Auburn University engineering undergraduate students), twenty one (n = 21) workers, and fifty two (n = 52) experts participated in this research. The number of worker responses is substantially lower than the number of naïve users and experts because of recruitment issues, hence, workers only participated in the reference group and not the recall group. Demographic information was collected and participants responded to

Table 5
Responses to yes/no questions and results of χ^2 test of independence for the relationship between the correct response and self-reporting referring to the SDS to answer the question.

Question	# correct responses and %	# which self-reported using the SDS to answer question and %	# which both correct response and referenced SDS and %	χ^2 (1, N = 266)
1 — Do you think this chemical is a carcinogen (may cause cancer)?	129 (49%)	163 (61%)	94 (35%)	14.18 $p < .001$
2 — Do you think this chemical is a mutagen (may cause genetic defects)?	68 (26%)	178 (67%)	52 (20%)	3.77
3 — Do you think this chemical is a teratogen (may cause developmental or reproductive issues)?	132 (50%)	173 (65%)	93 (35%)	3.38
4 — Do you think this chemical is flammable?	162 (61%)	178 (67%)	121 (45%)	11.31 $p < .001$
5 — Can this chemical mix with water?*	108 (41%)	167 (63%)	83 (31%)	15.40 $p < .001$
6 — Do you think this chemical must be stored in total darkness?*	139 (52%)	154 (58%)	85 (32%)	1.27
7 — Do you think this chemical can only be stored in an open drum?*	186 (70%)	139 (52%)	112 (42%)	15.70 $p < .001$
8 — Do you think this chemical can only be used if the worker wears a respirator?**	158 (59%)	169 (63%)	117 (44%)	18.58 $p < .001$
9 — Can you throw this chemical down the drain?***	210 (79%)	150 (56%)	127 (48%)	6.77 $p < .01$

* There was no pictogram present on either SDS related to this item.
** Chemical A had the pictogram for air purifying respirator and chemical B had the pictogram for full face respirator.
*** The SDS for chemical B had the environmental pictogram present in Section 2.

questions to establish their knowledge of hazard communication (Table 6). The responses for the 55 naïve users, the 21 workers, and the 52 experts did not contain any missing data. Participation was anonymous, with no direct identifiable information collected from any of the participants. Thus, all of the information collected was self-reported and not subject to verification by the investigators.

5.2. Materials

5.2.1. Labels

Labels for 12 different chemicals were used in this survey. The name of each chemical was replaced with a letter to help prevent previous knowledge from biasing the responses to the questionnaire. Hazard pictograms were placed on the left side of the label. The hazard pictograms were 2 cm wide and 2 cm tall, with a white background and a black pictogram surrounded by a red square on point. Precautionary pictograms were placed below the Response section following the textual description of the personal protective equipment (PPE). The precautionary pictograms were 2 cm wide and 2 cm tall, with a blue background and a white pictogram. As an example, Chemical A is shown in Fig. 3.

In the body of the text, 12-point Arial font with mixed case was used. The headings for Prevention, Response, Storage, and Disposal were 14-point, bold, Arial font using mixed case. The signal word "DANGER" for all 12 trials was all uppercase letters, 24-point, bold, Arial font. The chemical name alias was 26-point, bold Arial font with white text on a black background. The hazard pictograms were placed two per line and in the following order (if present) on the label: flame, flame over circle, exploding bomb, corrosive, gas cylinder, skull and crossbones, health hazard, and exclamation mark. The precautionary pictograms were placed on a single line in the following order (if present): self-contained breathing apparatus, goggles, safety glasses, full suit, gloves, apron, boots, air purifying respirator, and dust mask.

Table 6
Self-rating of HAZCOM knowledge by participants.

	N	Naïve Users	Workers	Experts
Participants	128	55 (43%)	21 (16%)	52 (41%)
Gender				
Male	88 (69%)	37 (67%)	19 (90%)	32 (62%)
Female	40 (31%)	18 (33%)	2 (10%)	20 (38%)
Self rating of HAZCOM knowledge				
Below average	13 (10%)	12 (22%)	1 (5%)	0 (0%)
Average	53 (41%)	38 (69%)	10 (48%)	5 (10%)
Above average	62 (48%)	5 (9%)	10 (48%)	47 (90%)

5.2.2. Survey instrument

The questionnaire covered the physical hazards, precautionary measures, potential health effects, preventive actions, and personal protective equipment (PPE). Equal emphasis was given to each of the information categories above. An online survey tool (www.qualtrics.com) was used to administer the questionnaire via the internet to participants.

For each of the 12 trials, participants were presented a GHS product label, and then were asked to respond to six items for each label. The first item asked participants how many hazard pictograms (pictograms surrounded by a red border) were present on the label. This item was intended to serve as a distractor task for the recall group and the data were not included in the analysis. The second survey item covered the physical hazards associated with the product. The third item pertained to potential health effects from exposure to the material. The fourth item covered preventive actions to reduce the potential for exposure to the product. The fifth survey item asked what type(s) of PPE should be worn when using the product. Finally, participants were asked to rate their level of perceived risk on a seven point Likert-type scale. The verbal anchors for the perceived risk scale were very low, somewhat low, moderate, somewhat high, high, and very high.

Survey items two through five were the survey items used to score each response. Each of these items was given equal weight in this analysis. In the event the label did not provide specific guidance for a particular survey item, participants were given full credit for that portion of the weighted response. For example, the sample label for Chemical E, did not provide any specific guidance for personal protective equipment. Therefore, all participants were given full credit for this item for Chemical E. The electronic survey tool also captured participant response times for individual survey items.

5.3. Procedure

The participants were presented 12 GHS format labels in random order using an electronic survey tool (www.qualtrics.com), after providing demographic information. A 2 × 2 block design with three repeated measures was used to manipulate the presence of the hazard pictograms and the precautionary pictograms for a total of 12 trials.

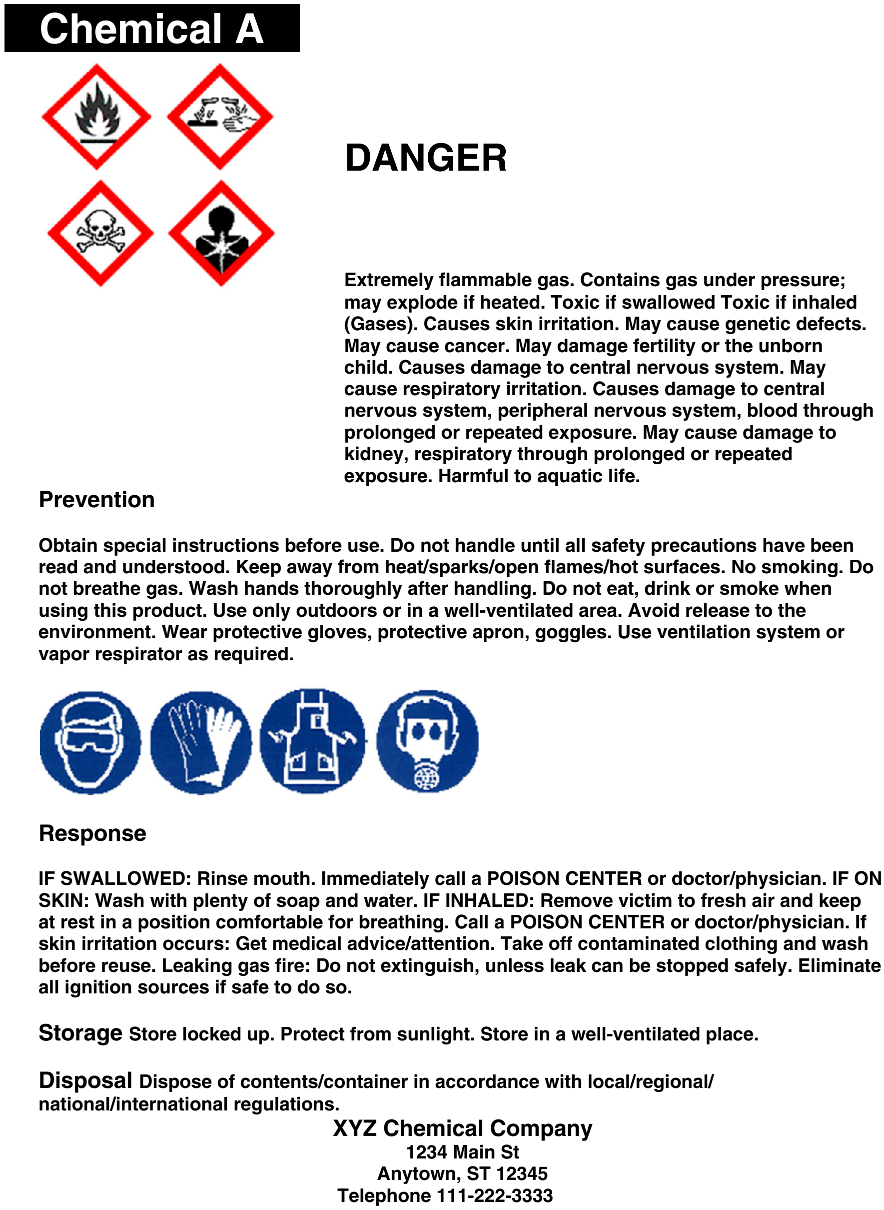

Fig. 3. Example of GHS product label with both hazard and precautionary pictograms for Chemical A.

For each of the conditions, three labels were created that would have been assigned either four, three, or two hazard pictograms under the GHS classification for that particular chemical. All 12 chemicals were assigned the signal word "Danger," which was not manipulated during the survey.

The naïve users and expert participants were divided into two groups: one had the label present on each screen and one group was presented the label, and then was asked to recall the information to respond to the survey questions. Both the label reference group and the recall group were presented a label prior to advancing to each group of survey questions. The label reference group was able to refer to the label to respond to each survey item. The recall group was instructed to read the label, and then respond to the survey items. Then the process was repeated with instructions to read the subsequent labels and to respond to the survey questions. The naïve users and the experts were randomly assigned to one of the groups, and all of the workers were assigned to the label reference group because of recruitment limitations. Repeated measures analysis of variance (ANOVA) was used to assess the effects of the presence of the hazard and precautionary pictograms and the participant's rating of perceived risk.

6. Results and discussion for label survey

There were 128 completed responses for this survey. Similar to Survey 1, the responses to the survey items and to open ended questions were subjectively evaluated by a panel of safety researchers ($n = 3$) to determine a point value and adhere strict grading criteria. An alpha level of 0.05 was used for all statistical tests.

6.1. Ability of GHS labels to convey information

Overall participants on average correctly responded to 86% of the material on the survey. For the reference group, the naïve users correctly responded to 89%, the workers correctly responded to 91%, and the experts correctly responded to 92%. For the recall group, the naïve users correctly responded to 80% and the experts correctly responded to 81% of the survey questions.

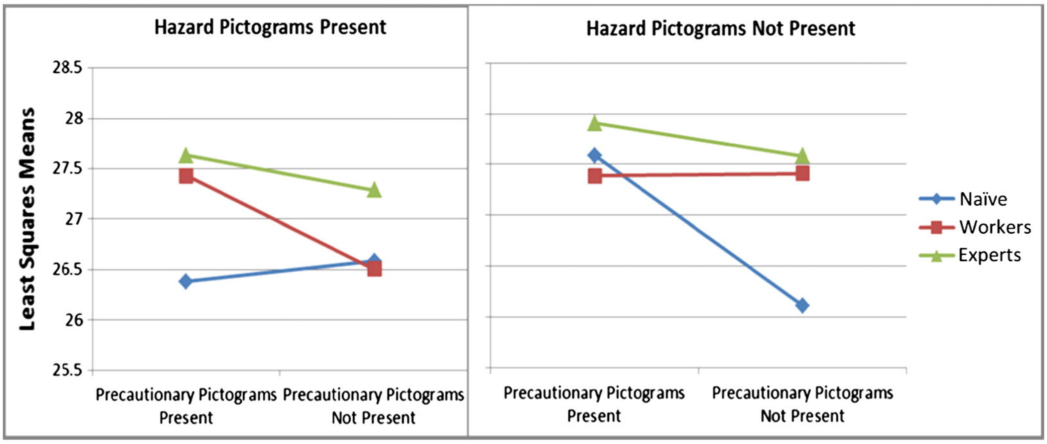

Fig. 4. Plots of average perceived risk ratings for naïve users and experts for the three way interaction of strata, hazard pictograms, and precautionary pictograms.

The data collected for the experts and the naïve users for both the reference group and the recall group (n = 107) were analyzed to determine the effects between the treatments. There was a significant main effect between the reference group and the recall group, F (1, 103) = 27.17, $p < .001$, with the reference group responding with a higher percentage of correct responses than the recall group.

6.1.1. Ability of GHS labels to convey information for the reference group

For the naïve users, workers, and experts in the reference group (n = 73), there was not a main effect for strata, $p = .23$. The hazard pictograms did not have a significant main effect on the participants correctly responding to the survey items, $p = .13$. The presence of the precautionary pictograms did have a significant main effect F (1, 70) = 5.36, $p = .024$. The three way interaction between hazard pictograms, precautionary pictograms, and strata was significant, F (2, 70) = 3.84, $p = .026$ (Fig. 4).

6.1.2. Ability of GHS labels to convey information for the recall group

For the naïve users and experts in the recall group (n = 55), there was not a main effect for strata, $p = .77$. The hazard pictograms did have a significant main effect on the participants correctly responding a higher percentage of survey questions, F (1, 53) = 5.73, $p = .020$ and the interaction between hazard pictograms and strata was significant, F (1, 53) = 5.13, $p = .028$.

6.2. Perceived risk

For all participants, the effect of strata was significant for ratings of perceived risk, F (2, 125) = 3.25, $p = .042$. The participants indicated a higher rating of perceived risk when the hazard pictograms were not present, F (1, 125) = 13.66, $p < .001$ (Fig. 5). This is contrary to the research hypothesis that the presence of hazard pictograms would increase the perceived risk by participants. The presence of the precautionary pictograms did have a significant main effect, F (1, 125) = 26.12, $p < .001$, which increased the perceived risk rating by the participants (Fig. 6). The interaction between hazard and precautionary pictograms was significant, F (1, 125) = 12.94, $p < .001$. This interaction was significant because the presence of pictograms had an opposite effect on the perceived risk ratings for the hazard and the precautionary pictograms.

6.2.1. Perceptions of risk for GHS format labels for the reference group

For the naïve users, workers, and experts in the reference group (n = 74), there was a significant effect for the presence of the hazard pictograms, F (1, 71) = 9.68, $p = .003$. Participants provided higher ratings of perceived risk when the hazard pictograms were not present than when the hazard pictograms were present on the label (Fig. 7). This is contrary to the research hypothesis that the presence of hazard pictograms would increase the perceived risk by participants. The presence of the precautionary pictograms also was a significant effect, F (1, 71) = 22.4, $p = <.001$ (Fig. 8). The interaction between hazard pictograms and precautionary pictograms was significant, F (1, 71) = 14.93, $p = <.001$. This interaction was significant because the presence of pictograms had an opposite effect on the perceived risk ratings for the hazard and the precautionary pictograms (Figs. 7 and 8). There were no other significant effects between strata and condition.

6.2.2. Perceptions of risk for GHS format labels for the recall group

For the naïve users and experts in the recall group (n = 54), the presence of the precautionary pictograms did have a significant main effect F (1, 52) = 8.91, $p = .004$, with the participants indicating

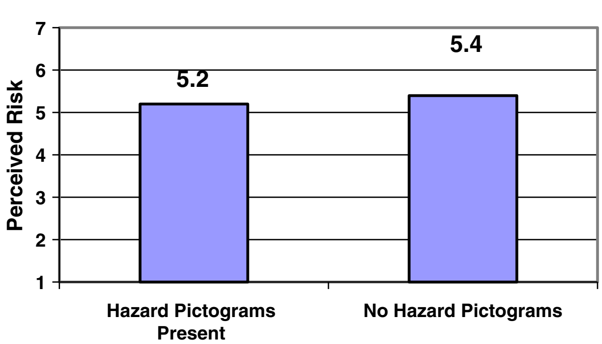

Fig. 5. Chart of average perceived risk for hazard pictograms for the naïve users and the experts in both the reference and recall groups.

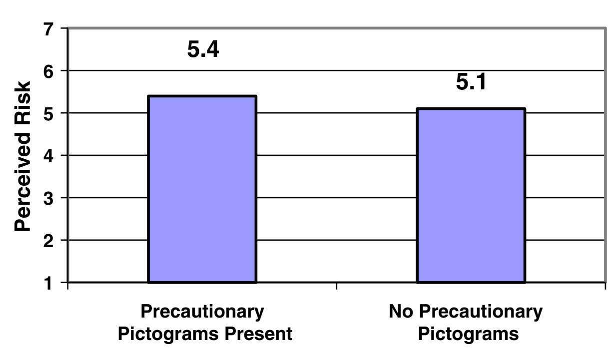

Fig. 6. Chart of average perceived risk for the precautionary pictograms for the naïve users and the experts in both the reference and recall groups.

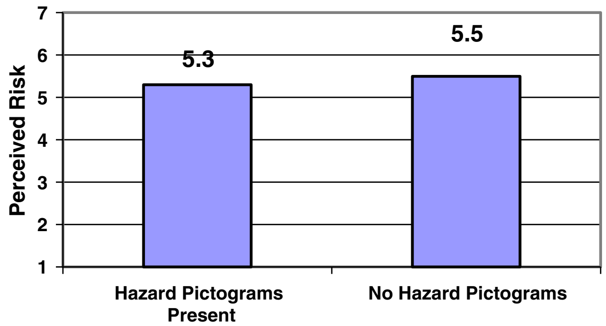

Fig. 7. Chart of average perceived risk for the hazard pictograms for the reference group.

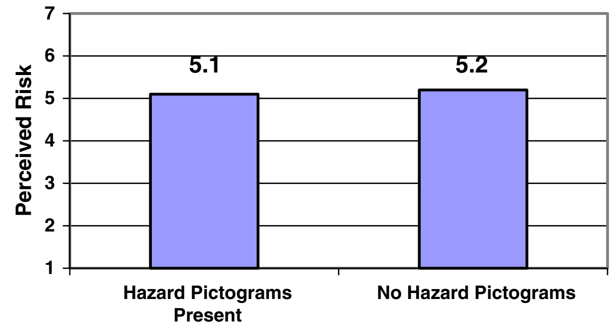

Fig. 9. Chart of average perceived risk for precautionary pictograms for the recall group.

higher ratings of perceived risk (Fig. 10). The interaction between hazard and precautionary pictograms was significant, F (1, 52) $=$ 5.47, $p = .023$, as well as the three-way interaction between hazard pictograms, precautionary pictograms, and strata, F (1, 52) $=$ 5.01, $p = .030$ (Fig. 11). The two way interaction was significant because the presence of pictograms had an opposite effect on the perceived risk ratings for the hazard and the precautionary pictograms (Figs. 9 and 10). For the three way interaction see Fig. 11, the naïve users and the experts both rated the perceived risk as higher for the labels when the hazard pictograms were not present and the precautionary pictograms were present, and the experts indicated a larger difference between the perceived risk ratings than the naïve users (Fig. 11).

6.3. Effect of label formats on response time

The survey tool was able to record the server side response times for the individual survey questions. The summations of the individual question response times for each label were used to test if there was a difference in the response time when the pictograms were present. For the reference condition, the presence of the hazard pictograms was not significant, $p = .75$. After the removal of the 13 outliers greater than 1.5 times the inter-quartile range, the effect of participants responding to the questions more quickly when the hazard pictograms were present did have a significant main effect F (1, 57) $=$ 10.94, $p = .002$.

7. Conclusions

7.1. Effects of pictograms

The results of this study suggest that the presence of pictograms may improve the communication of safety information. Hazard and precautionary pictograms may be used on SDS and labels and still be in compliance with the current Hazard Communication Standard (OSHA, 1994), and during the transition period until June 2015 when the revised HCS will be in effect. At that time, the use of hazard pictograms or the names of the hazard pictograms on SDS will be required by OSHA. The use of precautionary pictograms was not addressed in the third revised edition of the GHS (United Nations, 2009a) or the final rule for the HCS issued by OSHA in 2012. Interestingly, the sample SDS used for comprehension testing performed by the United Nations Institute for Training and Research (UNITAR, 2007) did not have GHS hazard pictograms or the names of the pictograms present on the SDS.

In the SDS survey, the presence of the hazard pictograms for the physical hazards was significant, with participants better acknowledging the physical hazards when the pictograms were present. This may be in part to a one-to-one correlation between a hazard pictogram and a physical hazard. Notwithstanding, if the material is assigned the health hazard pictogram and/or the exclamation mark pictogram, this may attempt to communicate one or more potential hazards. The use of precautionary pictograms on the SDS was significant for Chemical B, t (131) $= -2.52$, $p = .0013$, but not for Chemical A.

In the label survey, the presence of the precautionary pictograms led to improved response rates to the survey items and to an increase in perceived risk ratings by the participants. This research suggests that there may be a benefit for including precautionary pictograms on GHS product labels. This finding was consistent across the naïve users, the workers, and the experts participating in this study. However, the applicability of this finding may be limited in practice because this study did not evaluate if the inclusion of the precautionary pictograms would alter behavior such as the increased use of personal protective equipment or other preventive actions that may reduce the risk of a potential exposure to a chemical product. Attempting to study realistic problems regarding safety information is challenging because measuring participants' precautionary behavior is difficult.

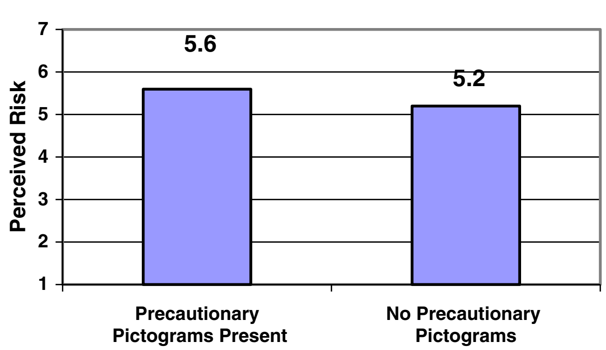

Fig. 8. Chart of average perceived risk for the precautionary pictograms for the reference group.

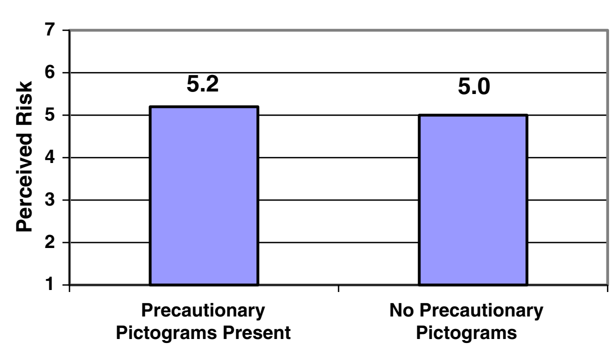

Fig. 10. Chart of average perceived risk for precautionary pictograms for the recall group.

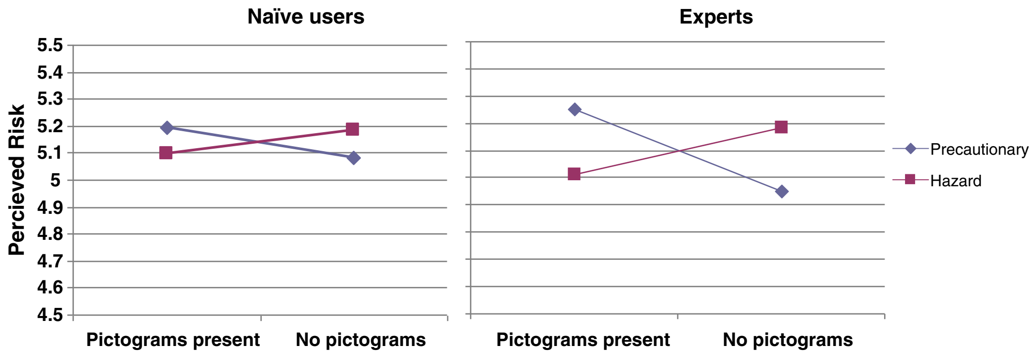

Fig. 11. Plots of average perceived risk ratings for naïve users and experts for the three way interaction of strata, hazard pictograms, and precautionary pictograms.

7.2. Effect of response time

After removing the outliers in the SDS survey, there was a significant difference between the response time when pictograms were present and when they were not, t (253) = 2.3, p = .022. Also in the label survey, the presence of the pictograms was also significant for the reference group. This finding should help support the use of pictograms on SDS and labels to serve as guide posts to help decrease the amount of search time users need to find information. These findings additionally provide support for the suggestion of Dorris and Purswell (1978) that graphic representations, or pictograms, may be recognized more quickly and have more intrinsic interest than written warnings.

7.3. Effect of user groups

In the SDS survey, the experts took longer to respond to the survey items and received higher scores than the naïve users when referring to SDS to respond to survey questions. This finding was not supported in the label survey. The effects in the SDS survey may suggest that the experts can rely on their familiarity with the types of information generally contained in a SDS and they are more willing to spend the time to search for the information. The lack of a finding in the label survey suggests that users, independent of their familiarity with hazard communication, are able to search the label for information and use the information to respond to the survey items.

One of the potential changes to the format of GHS SDS documents is the label information will be included in Section 2. This may help users find needed information more quickly without searching the entire document or may assist users by providing an additional consistency check that the label on the product is for the same chemical as the SDS.

7.4. Limitations and future research

There were several limitations in these surveys. For the SDS survey, data were not collected from industrial workers, which the HCS is intended to protect. After the GHS hazard pictograms are required as part of the HCS in 2015, then it may be possible to evaluate the effects of training for the standardized pictograms. Even though participants from groups with different levels of experience participated in this study, future research should be conducted regarding the effects of education and literacy levels. Participants in this study were able to read and were also computer literate to be able to respond to the surveys. While GHS hazard and precautionary statements have been translated into a number of languages, studies should examine comprehensibility issues between potential users from different nations. Future research should attempt to address these limitations and continue to examine alternatives to improve comprehension of hazard communication.

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