Research Paper

Assessing the Cognitive Sign Features and Guessability of Laboratory Safety Signs for Pharmacy Students

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ABSTRACT

Background and Purpose: Correct recognition of hazards in academic labs by using safety signs can prevent injuries in these settings. Although safety signs seem simple, misunderstanding them can put students at risk. Therefore, this research aims to assess the cognitive sign features and guessability of laboratory safety signs for pharmacy students.

Materials and Methods: In this study, the comprehensibility of 22 commonly used safety signs was evaluated by 55 pharmacy students aged 20-30 years from Mazandaran University of Medical Sciences, Iran. Two measures of guessability score and cognitive sign features were used to assess the safety signs. The guessability score was measured by a five-choice answering method, where there were correct, partly correct, and wrong answers. Cognitive sign features (familiarity, concreteness, simplicity, meaningfulness, and semantic closeness) rated from 0 to 100. SPSS software, version 23 was applied for data analysis. Data were analyzed using descriptive statistics, box plots, and the Spearman correlation test. The significance level was set at 0.05.

Results: The lowest guessability score was 1.08% for the "general mandatory action sign", and the highest score was 100% for the "no smoking" sign. Despite the varying responses, two "general mandatory action" and "disconnect before carrying out maintenance or repair" signs had significantly scattered coefficients of variation. According to the overall scores for cognitive sign features, the simplicity criterion had the highest score (85.73%). All cognitive sign features significantly correlated with guessability scores except for concreteness and familiarity. The highest coefficient was reported between guessability score and semantic closeness (r=0.469, P<0.001).

Conclusion: The lab safety signs without accompanying text or those that are not frequently encountered are difficult to be perceived correctly by pharmacy students.

Keywords: Safety sign, Guessability, Comprehensibility, Cognitive, Laboratories

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Introduction

Laboratory is an important place for research and learning in universities and institutes. In laboratories, students can practice based on the theoretical concepts learned in the classroom [1, 2]. In this regard, the laboratory work is a crucial part of the curriculum. There is strong evidence to support that chemicals and equipment in laboratories can be harmful to students or other people who work in this setting. Laboratory environments are known as places with numerous work-related hazards, such as long-lasting toxic gases and vapors, radiation, and gas cylinders. The students in the chemistry and pharmacy fields of study are constantly in contact with various laboratory chemicals or equipment. Irritating, toxic, flammable, corrosive, radioactive, and explosive features are the hazardous characteristics of chemicals that can cause skin burns, eye irritation, or death due to acute exposure [2]. Despite numerous risk factors in the laboratory environment, the use of an occupational health and safety (OHS) management system can significantly reduce unsafe incidents.

Improving unsafe behaviors is one of the main objectives of using safety signs [3]. In general, safety signs are labels with a specific color and shape that are used to represent safety instructions or information. They are widely used to draw attention to potential risks, prevent injuries, and ultimately reduce unsafe behaviors [4]. Safety signs can reduce the risk of occupational accidents [5]. Although safety signs are widely used, some do not have the necessary efficiency based on the defined purpose and cannot represent information properly [6]. Many safety signs do not meet the usability and effectiveness criteria and are often not evaluated by target groups before use. Therefore, evaluation of safety signs before installation is necessary to ensure comprehensibility and prevent misunderstanding. Five criteria have been proposed for evaluating the usability of products including guessability, learnability, experienced user performance, system potential, and re-usability [7, 8]. Moreover, some cognitive-related features have been recommended for evaluating signs, viz. familiarity, concreteness, simplicity, meaningfulness, and semantic closeness [9]. Familiarity refers to the rate at which people have frequently encountered the sign. Concreteness indicates the possible connections of the signs with the real objects. Simplicity refers to the degree to which the signs are detailed. Meaningfulness refers to how much a sign is considered meaningful by people. Semantic closeness indicates the closeness of the relationship between what a sign depicts and what it wants to represent. These features are related to cognitive ability and individuals' perception [10]. Several studies have shown that the success of a sign in representing a message depends on both the demographic characteristics of people and these five cognitive features [4, 11].

In literature, the comprehension of safety signs has been assessed in students, workers, and disabled people [4, 11]. Duarte et al. assessed the comprehension of safety signs by students, adult workers, and disabled people. According to their results, students had the highest comprehension (42%), followed by workers (39%) and disabled people (21%) [4]. Banstola found that only 49% of final-year pharmacy students at an Indian college were aware of pharmacy pharmaceutical symbols [12]. The comprehension evaluation among diverse populations should be conducted to compare and increase the generalizability of the results. Several studies have revealed that older adults or people with low education levels are less able to understand safety signs [13-16].

Students frequently adhere to laboratory safety procedures, but there are still violations that have resulted in accidents and fatalities in the laboratory [17]. Some studies have revealed that students have misunderstandings and are unaware of the use of hazardous chemicals [18]. Wiediger and Hutchinson stated that if students misunderstand the information provided on chemical containers, there will be a risk of an accident in the laboratory [19]. however, no study has examined the cognitive features and comprehensibility of safety signs in Iranian pharmacy students who are continuously present in laboratories. There is a critical gap in the effectiveness of laboratory safety signs for pharmacy students. Therefore, this research aims to assess the cognitive sign features and guessability of laboratory safety signs in Iranian pharmacy students.

Materials and Methods

Study design and participants

This descriptive-analytical study was conducted during 2021-2022. The study population consists of pharmacy students from Mazandaran University of Medical Sciences who are completing practical courses in a lab environment. The sample size was determined utilizing a single population proportion formula, considering a 95% confidence interval, test power of 90%, proportion of 0.5, and a margin of error of 0.05. Sixty-one male

Table 1. The safety signs used in the study, adapted from ISO 7010

Code	Sign	Sign Meaning	Code	Sign	Sign Meaning
01		First aid	02		Safety shower
03		Fire extinguisher	04		Do not touch
05		Oxidizing substance	06		Eyewash station
07		General mandatory action sign	08		Refer to instruction manual/ booklet
09		Wear eye protection	10		Disconnect mains plug from electrical outlet
11		Wear protective gloves	12		Wear a face shield
13		Disconnect before carrying out maintenance or repair	14		General prohibition sign
15		No smoking	16		Not drinking water
17		Do not extinguish with water	18		General warning sign
19		Electricity hazard	20		Toxic material

Code	Sign	Sign Meaning	Code	Sign	Sign Meaning
21		Flammable material	22		Corrosive substance

and female students were selected to participate in the study. The inclusion criteria were age 20-30, active participation in practical laboratory courses, and normal color vision based on a standard assessment. Exclusion criteria were prior laboratory experience (whether through coursework, workshops, or research involvement) and unwillingness to continue participation after providing informed consent. Finally, 55 students participated in this study.

Safety signs

According to international and national standards, there are many laboratory safety signs that primarily focus on alarming hazards or preventing unsafe behaviors. In this study, ISO 7010 was used to get a list of graphical safety signs [20]. The most common safety signs in the academic laboratories were selected based on the frequency of use, hazard level, clarity, and universality and according to the opinions of five experts (three laboratory specialists with more than 10 years of experience and two academic researchers in the field of safety and ergonomics). The signs were selected because their meanings are perceived only through symbols and were not combined with other signs to communicate a message. Also, in a previous study, these signs had guessability lower than 60% [3]. The safety signs should have the following features to be included in the experiment: Being the label of chemicals or equipment, observation by experts in other laboratories, and being simple or useful. Finally, 22 safety signs were selected and categorized into four groups: Guide signs (n=4), mandatory signs (n=7), prohibition signs (n=5), and warning signs (n=6). The code and meaning of safety signs are presented in Table 1.

Instrument

A questionnaire was designed to assess the color vision status of students and record their demographic information. The study objectives and instructions were explained to them before the experiment, followed by a computer presentation of the questionnaire. The first part of this questionnaire surveys demographic information. In the second part, a color vision test [21] was used to screen out those who had red-green color problems. The experiment was conducted using a Samsung tablet with a 12-inch LED screen. The safety signs were presented on the tablet in a uniform size as Microsoft PowerPoint slides so that the subjects could examine the signs self-paced.

Quessabiliy test

The guessabiliy test was designed based on a previous study in this field [3]. Five non-listed safety signs were shown to the participants as a trial to ensure the procedure was correctly understood. Then, 22 safety signs were randomly presented, and the students were asked to guess their meaning within 10 seconds. For each safety sign, there were five verbal labels: One correct answer, two partly correct answers, and two wrong answers. For example, the five labels for code 04 were “do not enter your hands,” “risk of injury to the hands,” “do not take the items,” “do not touch,” and “handling without personal protective equipment is prohibited.” The correct answer should be “do not touch”; the partly correct answers were “do not enter your hands”, “risk of injury to the hands”, and the wrong answer was “do not take the items” and “handling without personal protective equipment is prohibited”. Participants received a score of two marks if they chose the correct answer. A score of one mark was given for partially correct answers, and a zero mark for the wrong answers [3]. No feedback for guessing performance was provided. This approach continued until the individual gave the guessed answers for all the signs. To prevent fatigue, a 1-minute break was provided after testing 22 signs.

Safety sign feature evaluation

The participants were briefed about the meanings of cognitive features. Five cognitive criteria (familiarity, concreteness, simplicity, meaningfulness, and semantic closeness) were used to assess cognitive sign features [22]. The participants were asked to give a rating from 0 to 100 for familiarity (0=very unfamiliar to 100=very familiar), concreteness (0=definitely abstract to 100=definitely concrete), simplicity (0=very complex to 100=very sample), meaningfulness (0=completely meaningless to

Table 2. The rating scale for evaluation of cognitive sign features [3]

Characteristic		Description	
Familiarity	Definition	Familiarity is defined in terms of the frequency with which a sign has been encountered.	
	Evaluation criterion	Very unfamiliar 0	Very familiar 100
	Example		
Concreteness	Definition	A sign is considered as concrete if it depicts objects which have obvious connections with the real world, and considered as abstract if it does not.	
	Evaluation criterion	Definitely abstract 0	Definitely concrete 100
	Example		
Simplicity	Definition	A sign is regarded as complex if it contains a lot of details or is intricate, and as simple if it contains few elements or little detail.	
	Evaluation criterion	Very complex 0	Very sample 100
	Example		
Meaningfulness	Definition	Meaningfulness refers to how meaningful the participant perceives a sign to be.	
	Evaluation criterion	Completely meaningless 0	Completely meaningful 100
	Example		
Semantic closeness	Definition	Semantic closeness is a measure of the closeness of the relationship between what is depicted in a sign and the function it is intended to represent.	
	Evaluation criterion	Very weakly related 0	Very strongly related 100
	Example		

100=completely meaningful), and semantic closeness (0=very weakly related) to 100=very strongly related) as shown in Table 2. A 0–100 point scale was used because of its high reliability and validity [23].

Statistical analysis

The data from returned questionnaires were coded and entered into Microsoft Excel. The statistical analysis was carried out in SPSS software, version 23. The Kolmogorov-Smirnov test was used to evaluate the normality of the data distribution. Data were analyzed using descriptive statistics, box plots, and the Spearman correlation test. P<0.05 was considered statistically significant.

Results

In this study, 48% of the participants were male. The mean age of participants was 24.2±3.9 years. None of them had color vision problems.

Guessability test results

In this study, the guessability test score indicates the accuracy in guessing the correct meaning of each safety sign. The Kolmogorov-Smirnov test results showed that the guessability ratings for the signs were not normally distributed (P<0.05). The descriptive statistics of guessability scores for the safety signs are presented in Table 3. The lowest mean score was 1.08% for the general mandatory action sign (code 07), and the highest

Table 3. The mean guessability scores for safety signs

Safety Sign	Mean±SD	Safety Sign	Mean±SD
	70±45.2		39.92±40.9
	32.22±32.8		10.24±30.3
	73.68±38.2		67.8±31.4
	77.92±40.3		100±0
	49.4±17.9		66.24±43.3
	81.96±31		62.84±43.6
	1.08±3.9		41.2±39.9
	54.56±37.7		92±25.5
	48.76±42.2		61±45.3
	46.8±43.2		98±14.1

Safety Sign	Mean±SD	Safety Sign	Mean±SD
	29.12±32.9		83.36±36

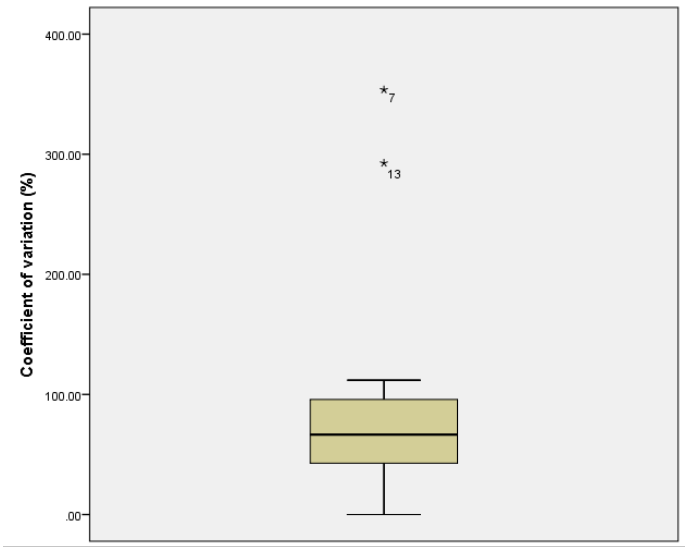

Figure 1. Box plot of coefficients of variation on guessability score for all signs

Notes: Two outliers (codes 7 and 13) are flagged with a star.

mean score (100%) was for no smoking (code 15). Mean scores of the guessability test for the safety signs based on categories (guide, mandatory, prohibition, and warning) are shown in Table 4.

The box plot was used to check if there was a significant difference in the variability of the guessability score between the signs (Figure 1). The general mandatory action sign with code 07 (353.72%) and disconnect before carrying out maintenance or repair with code 13 (292.65%) were illustrated as outliers above the box, indicating that the dispersion of guessed answers for these two signs was more than for other signs. The mean guessability score for all safety sign groups was more than 50%, and the total Mean±SD were 70.2% and 14%, respectively.

Table 4. Guessability scores (%) for the safety sign categories

Category	Mean±SD	Coefficient of Variation	Min	Max
Guide	69.33±20.58	29.68	16.67	100
Mandatory	55.28±12.81	23.17	22.86	85.57
Prohibition	78.04±14.96	19.16	40	100
Warning	78.16±12.35	15.8	41.67	100
Total	70.2±9.3	13.214	44.05	86.61

Table 5. Mean scores of the criteria for cognitive sign features evaluation

Safety Sign	Mean±SD				
	Familiarity	Concreteness	Simplicity	Meaningfulness	Semantic Closeness
	54.4±33.16	70.2±22.51	80.9±22.31	71.9±23.68	76.2±29.19
	51.5±37.83	67.9±32.8	77.7±34.76	74.2±30.39	83.3±27.66
	68.9±33.3	82.2±24.43	84.1±19.82	85±20.6	83.6±27.09
	53.7±31.46	72.7±27.1	75.7±25.37	76.2±23.35	88.1±21.86
	50.7±30.96	61.7±29.57	65.2±29.94	69.8±27.88	34.5±31.59
	61.7±34.8	78.3±23.63	80.2±23.25	80.5±22.54	90.4±16.93
	31.1±35.01	36.3±35.84	63.4±37.28	45±35.86	23.8±30.57
	40±34.23	62.5±30.3	68.2±31.42	61.4±33.42	64.5±36.19
	64.9±35.76	74.5±27.66	78.5±27.41	77.9±29.05	90.7±17.24
	47.1±36.83	68.5±30.64	68.6±31.74	73.9±28.27	86.8±21.53

Safety Sign	Mean±SD				
	Familiarity	Concreteness	Simplicity	Meaningfulness	Semantic Closeness
	69.8±31.95	85.9±20.31	88.1±17.08	89.1±17.65	97.2±8.25
	58±38.1	78.7±26.84	82.4±22.41	84.8±20.97	89.8±23.23
	21.1±33.05	21.1±31.8	31.9±35.53	26.6±36.19	15.8±31.71
	90.5±17.92	87.2±24.74	91.2±19.17	87.2±23.96	75±31.39
	96±8.6	95.2±10.43	95.4±10.06	94.7±14.67	98.4±6.11
	63.9±36.12	77.6±30.38	76±29.83	79.8±25.9	76.9±31.95
	65±36.75	73.9±28.48	75.6±29.59	75.2±29.88	71.4±33.94
	68.8±33.06	74.3±32.57	76.9±30.29	75.6±30.34	75.2±32.2
	77.2±28.82	81.9±28.03	82.4±26.44	84.2±25.56	87.2±26.12
	83.2±24.01	84.8±21.6	83.7±23.07	87.1±21.93	80.2±29.1

Safety Sign	Mean±SD				
	Familiarity	Concreteness	Simplicity	Meaningfulness	Semantic Closeness
	86±22.93	86.9±20.19	87.4±20.13	89.1±18.69	91.9±15.71
	77.1±29.24	87.4±21.17	83.4±23.26	88.2±20.77	92.3±16.92

Cognitive sign feature evaluation results

Table 5 reports the descriptive statistics for the cognitive feature evaluation of safety signs. Approximately, the mean scores of the cognitive features for all signs were at the mid-point (50) of the 0-100 scale, indicating that all five criteria for the safety signs were met, except for code 13 (disconnect before carrying out maintenance or repair).

The ratings of cognitive sign features in different categories are presented in Table 6. The highest value for familiarity was 73.82% (for prohibition and warning signs); for concreteness, 81.30% (for prohibition signs); for simplicity, 82.78% (for prohibition signs); for meaningfulness, 82.62% (for prohibition signs); and for semantic closeness, 83.30% (for guide signs). Overall, the simplicity criteria had the highest value (85.73%). Code 15 (no smoking) had the highest score (in terms of familiarity), whereas code 13 (disconnect before carrying out maintenance or repair) had the lowest score (in terms of semantic closeness).

The relationship between guessing score and cognitive sign features

The coefficients of correlation between cognitive sign features and guessability score are shown in Table 7. The results indicated that all cognitive sign features significantly correlated with guessability scores except for concreteness and familiarity. The highest coefficient was reported between guessability score and semantic closeness ($r=0.469$, $P<0.001$).

Discussion

This study measured the comprehension of commonly used laboratory safety signs in Iranian pharmacy students and examined the effect of cognitive sign features on the guessability of signs. Out of 22 safety signs assessed in this study, only 10 signs met the ISO 9186:2001 acceptance criteria, indicating that students cannot perceive the messages of the lab safety signs. The sign “disconnect before carrying out maintenance or repair”, which was graphically very simple, had a low cognitive score. Recently, studies have focused on prospective-user factors as a strong predictor of guessing performance, such as driving, working at laboratories or construction sites, laboratory or construction site visit experience, and injury experience due to ignorance of safety signs [3, 24, 25]. In this study, we did not investigate prospective-user factors since the safety signs utilized in pharmaceutical labs in Iran are not well defined. There has been no study on the relationship between the cognitive features and guessability of the meaning of the laboratory safety signs among pharmaceutical students to compare the results.

Consistent with previous studies, the safety signs that had less decorative details and were more generally simple scored higher guessability scores. As mentioned above, only 10 signs obtained the ISO 9186:2001 acceptability criteria (67%) [26]. The signs “no smoking” and “flammable materials” got the highest guessability score, while “the general mandatory action sign” and “disconnect before carrying out maintenance or repair” had the lowest score. It seems that if people do not encounter safety signs frequently, it will be difficult for them to understand [11, 27]. Generally, the “no smoking” signs are installed in public places, classrooms, and dormitories. In addition, the safety signs related to fire, such as the location of fire extinguishers or emergency exits, are present in faculties and are often encountered by students. The two signs with the lowest guessability score were related to the signs that people rarely en-

Table 6. Descriptive characteristics of cognitive sign features for the safety signs categories

Category	Criteria	Mean±SD	Coefficient of Variation (%)	Minimum	Maximum
Guide (n=4)	Familiarity	55.86±24.99	44.74	0	100
	Concreteness	72.14±19.73	27.35	33.33	100
	Simplicity	79.6±17.92	22.51	40	100
	Meaningfulness	75.53±19.12	25.31	16.67	100
	Semantic closeness	83.3±15.58	18.7	36.67	100
Mandatory (n=7)	Familiarity	47.43±22.81	48.09	10	91.43
	Concreteness	61.07±17.87	29.26	17.86	90
	Simplicity	68.72±18.82	27.39	21.43	95.71
	Meaningfulness	65.53±18.35	28	22.14	100
	Semantic closeness	66.94±13.84	20.68	41.43	100
Prohibition (n=5)	Familiarity	73.82±17.3	23.44	40	100
	Concreteness	81.3±14.75	18.14	50	100
	Simplicity	82.78±14.87	17.96	50	100
	Meaningfulness	82.62±17.52	21.21	16	100
	Semantic closeness	81.96±15.48	18.89	40	100
Warning (n=6)	Familiarity	73.82±19.08	25.85	21.67	100
	Concreteness	79.5±16.58	20.86	25	100
	Simplicity	79.84±15.95	19.98	25	100
	Meaningfulness	82.32±15.27	18.55	27.5	100
	Semantic closeness	76.88±14.55	18.93	40	98.3
Total (n=22)	Familiarity	62.73±15.72	25.06	26.9	94.8
	Concreteness	73.5±12.93	17.59	41.61	96.43
	Simplicity	85.73±29.56	34.48	42.11	47.6
	Meaningfulness	76.5±13.17	17.22	43.76	100
	Semantic closeness	77.27±10.18	13.17	52.12	91.33

countered them. Rosson and Carrol suggested that the familiarity criterion should be considered in designing safety signs [28]; however, it may not be easy since a sign familiar to a person may not be familiar to others.

Consistent with other studies [3, 11], the results showed that the guessability scores were higher for the signs that had better cognitive features (e.g. simple and concrete signs). As mentioned above, previous experience can play a critical role in correct comprehension of safety signs. It can also be true about cognitive features. For instance, the sign "disconnect before carrying out maintenance or repair" with the lowest guessability score, surprisingly had the lowest score based on cognitive sign features evaluation, because the students had no previous experience or could not adapt to a real shape. This confirms that appropriate cognitive sign features alone cannot be relied upon to convey messages

Table 7. Correlation coefficients between cognitive sign features and guessability score

Variables	1	2	3	4	5	6
Familiarity	-					
Concreteness	0.540**	-				
Simplicity	0.417**	0.856**	-			
Meaningfulness	0.274	0.713**	0.805**	-		
Semantic closeness	0.304*	0.381**	0.407**	0.432**	-	
Guessability score	0.166	0.235	0.335*	0.297*	0.469**	-

*Significant correlation at the 0.05 level, **Significant correlation at the 0.01 level.

correctly. In some previous studies, when people gave higher comprehension scores for simple signs than for more complex signs, one of the simple signs had the lowest cognitive sign features [29, 30], which is not consistent with this claim. It is important to note that cultural and social differences may be the reasons for these discrepancies. People face problems in different ways according to their thinking styles [31]. Although the validity of the Persian version of the questionnaire for cognitive sign features evaluation has been confirmed [32], further studies are recommended, especially on using other rating systems [33].

Despite this study reporting a causal relationship between guessability and cognitive sign features, there were possible limitations that should be considered. In our study, the participants were young college students. Therefore, it should be cautious about generalizing the results to older people. We used a multiple-choice test to evaluate the guessability of signs. A multiple-choice test lacks ecological validity in capturing the real-world issue of sign comprehension compared to an open-ended test [34]. However, we used a multiple-choice test because of its efficiency, low requirement for cross-checking, excellent inter-rater reliability, and content coverage in tests [35].

Conclusion

This study revealed the important role of guessability and cognitive sign features for the lab safety signs in conveying their message. The lab safety signs without accompanying text or those that are not frequently encountered are difficult for pharmacy students to be perceived correctly.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Mazandaran University of Medical Sciences, Sari, Iran (Code: IR.MAZUMS.REC.1399.8363).

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Authors contributions

Conceptualization and study design: Hajiomid Kalteh and Siavash Etemadinezhad; Analysis, data interpretation, and writing the original draft: Jamshid Yazdani Cherati, Siavash Etemadinezhad, and Solale Ramzani; Review and editing: Hajiomid Kalteh, Aghigh Salarian, and Solale Ramzani; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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