EFFECTIVENESS OF PICTOGRAM INSTRUCTIONS FOR DONNING SMOKE HOODS

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Smoke hoods or respiratory protective emergency devices (RPEDs) are marketed to assist in evacuation from fire emergencies. Many smoke hood manufacturers often rely on pictograms to instruct proper donning procedures to smoke hood users. Comprehending the instructions delivered through pictograms plays an important role in properly donning a smoke hood, and avoiding further injuries or complications from improper usage of the smoke hood. The purpose of this study was to determine the effectiveness of pictogram instructions used by three types of smoke hoods for donning a smoke hood. Results of this study indicate that the type of pictogram instructions have a significant effect on the ability of a user to properly don a smoke hood. While detailed pictogram instructions help users properly don smoke hoods, they also have an impact on the time required to don a smoke hood.

INTRODUCTION

Fire emergency escape devices such as smoke hoods are marketed to assist in evacuation from fire emergencies. The purpose of these devices is to protect evacuees from toxic gases and other particulate matter during the evacuation of a structural fire. Manufacturers of smoke hoods must comply with standards specified by ASTM E2952: American National Standard for Air-Purifying Respiratory Protective Smoke Escape Devices. This standard provides manufacturers with design guidelines and performance requirements which include a donning test. To pass the donning test, one male and one female user who have never donned a smoke hood, shall have 120 seconds to view the package instructions for the smoke hood and don it correctly (ASTM E2952, 2014). The U.S Consumer Product Safety Commission evaluated the usability of smoke hoods including function, durability, and human factors concerns (Khanna, 2007). Research suggests that visual aids are superior to written instructions as they overcome user language and comprehension barriers (Garcia-Retamero and Cokely, 2013). Many smoke hood manufacturers rely on sequenced pictograms as the only communication method to transmit smoke hood donning instructions.

Pictogram design employs graphical symbols such as icons and graphical features to enhance communications especially to people with different language backgrounds (Özcan and Van Egmond, 2004). The design of pictograms is not universal, as some designs are recommended by the International Standards Organization (ISO), while others are agreed upon by manufacturers (Bocker, 1996). Comprehension of smoke hood donning pictogram instructions is crucial due to the importance of properly wearing this device to avoid smoke and toxin inhalation, and the limited time available to evacuate a harmful environment. Well-designed pictograms can deliver information to the user more efficiently than plain text (Mansoor and Dowse, 2003; Boelhouwer, et al., 2013). Similar to aircraft emergency briefing cards that need to be designed for passengers who do not have a sufficient understanding of the emergency equipment and operating procedures (Corbett and McLean, 2008), pictogram illustrations need to consider that most users of smoke hoods do not have any prior experience using smoke hoods. A previous study indicated that there is a dramatic learning curve between the first and second time donning a smoke hood (Davis, et al., 2015)

The American National Standards Institute (ANSI) provides guidelines on safety sign and symbol comprehension. ANSI Z535.3 considers four

comprehension categories when testing the effectiveness of safety symbols: correct answer, critical confusion, wrong answer, and no answer. However, little guidance is provided on how to judge the "correctness" of an answer (ANSI Z535.3, 2011). The lack of standardized guidelines for testing the effectiveness of sequenced pictograms can potentially impact the ability to interpret messages and make correct decisions (Rother, 2008; Caffaro and Cavallo, 2015). While previous studies have indicated that pictograms such as warning symbols aid users, minimal research has been conducted on the effectiveness of sequenced pictograms to portray step by step instructions, such as donning a smoke hood. The purpose of this study was to determine the effectiveness of sequenced pictogram instructions for donning a smoke hood.

METHODS

Subjects

Forty-four subjects (23 females and 21 males) participated in the study conducted as a portion of a graduate industrial hygiene course during the fall 2016 semester. Retrospective study approval was obtained from the Auburn University Institutional Review Board (IRB). Subject age ranged between 19 and 30 years old ($\bar{x}$ = 20.8 years old, SD = 2.06). Subjects were excluded if they had previously donned a smoke hood, reported that they currently/recently had any respiratory illness, or if they could not lift their arms above their head. Inclusion criteria also included the ability to read and write in English, as demonstrated by their ability to fill out a short screening survey.

Experimental Design

Subjects were initially shown a two-minute PowerPoint presentation describing a smoke hood and their applications for familiarization. Additionally, three types of commercially available smoke hoods were presented to the participants as shown in Figure 1. Subjects were then told that they would have two minutes to view a set of pictograms (Figure 2) corresponding to one of the smoke hoods. A questionnaire was provided to each subject asking them to write down what they believed each pictogram was instructing them to do. Each participant completed the questionnaire for the pictograms corresponding to the three smoke hoods. The order in which each set of pictogram instructions were provided to the subjects was randomized. The orders and the number of subjects in each order are summarized in Table 1.

Table1: Orders and Number of Subjects

Type of order	Orders	Number of Subjects
1	ABC	8
2	ACB	7
3	BAC	7
4	BCA	7
5	CAB	9
6	CBA	6
	Total	44

Subjects' ability to follow the pictogram instructions was also tested by having them don the smoke hoods immediately following the questionnaire. A researcher instructed the subjects to don the smoke hood placed on a table in front of them, while being timed using a stopwatch. The time was measured when a subject received a signal from the researcher to start the donning process until the subject had donned the smoke hood and signaled to the researcher that they believed they had completed the donning procedure.

The researcher then inspected the donned smoke hood to determine if they met the three following criteria: (1) filter was placed over the subject nose and mouth; (2) a sufficient seal around the subjects' neck was obtained; and (3) during the donning process of "smoke hood B," the researcher also checked if the subject tightened the straps to ensure a proper seal. A binary system was used to record subject ability to don a smoke hood based upon these criteria and a scoring system was used to rate the "correctness" of donning a smoke hood.

Figure 1: Smoke Hoods

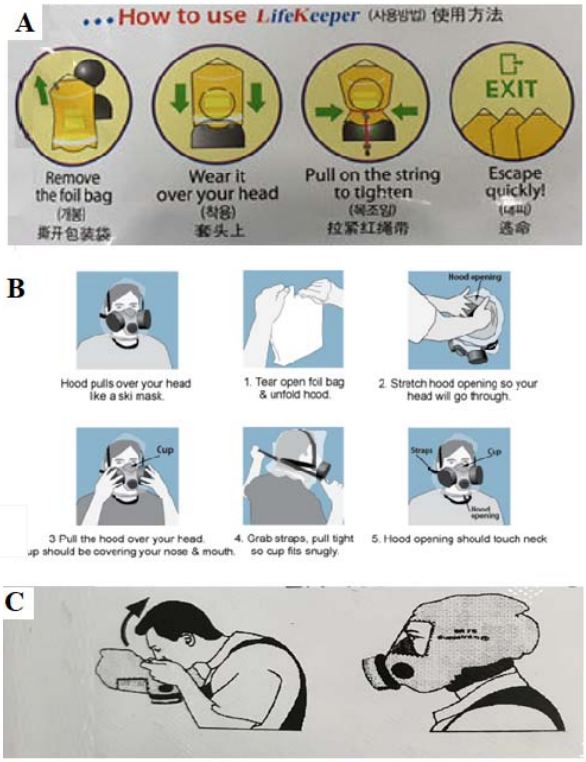

Figure 2: Smoke Hood Pictogram Instructions

Data Analysis

An Analysis of Variance (ANOVA) was used to determine if there was a significant difference between donning times of smoke hoods, and the ability to meet the three criteria of donning a smoke hood properly. The effectiveness of each pictogram instruction was analyzed by comparing the percentage of correct answers in the questionnaire to each set of of pictogram instructions. Donning time was also analyzed to determine if a correlation existed between donning time and the subjects' ability to meet the criteria of properly donning a smoke hood.

RESULTS

The mean donning times for each smoke hood are reported in Table 2. An ANOVA analysis followed by a Tukey's test indicated that the mean time to don "smoke hood B" is statistically greater than the time required to don "smoke hood A" and "smoke hood C" ($p < 0.001$).

Table 2: Mean Smoke Hood Donning Times (seconds)

Smoke Hood	N	Mean	SD
A	44	14.15	5.89
B	44	21.93	11.32
C	44	11.60	3.92

As illustrated in Table 3, the data suggest that the three different sets of pictogram instructions had a statistically significant effect on subjects' ability to properly identify the correct procedures of donning a smoke hood and the order of donning smoke hoods for each subject did not affect their ability to properly identify the correct procedures of donning a smoke hood. Table 4 illustrates the ANOVA analysis for the effect of percentage comprehension on the donning time. The results indicated that percentage comprehension of pictogram instructions had a significant effect on donning time. Percent comprehension for the pictogram instructions of "smoke hood A" was 98.9% whereas the comprehension for "smoke hood B" and "smoke hood C" were 84.6% and 50.0% respectively.

Table 3: ANOVA Percentage Comprehension vs Pictogram Instructions

Source	DF	SS	MS	F	P-value
Pictogram Instructions	2	5.39	2.70	45.77	< 0.001
Order	5	0.47	0.09	1.59	0.169
Error	124	7.30	0.06		
Lack of fit	10	0.71	0.07	1.23	0.277
Pure error	114	6.59	0.06		
Total	131	13.16			

Table 4: One-way ANOVA Donning time vs. Percentage Comprehension

Source	DF	SS	MS	F	P-value
Percentage Comprehension	5	1420	283.97	4.07	0.002
Error	126	8789	69.76		
Total	131	10209			

The criterion for wearing each smoke hood were also analyzed. The data suggest that "smoke hood B" had statistically significant higher average criteria points (2.6/3.0) compared to "smoke hood A" which had average criteria points of 2.2/3.0, and "smoke hood B" which had average criteria points of 2.1/3.0.

DISCUSSION

In this study, the data collected suggested that proper donning of a smoke hood is dependent on the understanding of pictogram instructions. As stated in the results, "smoke hood B" had the highest average score criteria. As shown in Figure 2, "smoke hood B" had pictogram instructions along with detailed written instructions which are hypothesized to result in

measured comprehension of the instructions required to don the smoke hood. However, the donning time of "smoke hood B" was found to be significantly greater than the donning time of the two other smoke hoods. This could be a result of the large amount of information provided in the pictogram instructions. Additionally, to properly don "smoke hood B" subjects had to tighten the straps on the smoke hood, a step that was not required when donning smoke hood "A" and "C".

While "smoke hood C" had the fastest donning times, it also had the lowest average criteria score points. As shown in Figure 2, the pictogram instructions of "smoke hood C" contained only two images instructing a user to place the smoke hood over their head. No instructions were provided to ensure that a proper seal was formed between the mask in the smoke hood and the breathing passageways of the user.

When comparing the subject's responses on the questionnaire to their ability to don a smoke hood, it was evident that subjects may not be able to accurately describe the pictogram sequence instructions, though they were able to use the pictograms to properly don a smoke hood. This may suggest that using a questionnaire method to determine the effectiveness of pictograms may not be as appropriate as simply asking users to demonstrate what they believe the pictograms are instructing them to perform. Additionally, having different sets of pictogram instructions for the same smoke hood would assist in better understanding the effectiveness of different pictogram design criteria.

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