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Investigation of guessability of industrial safety signs: Effects of prospective-user factors and cognitive sign features

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ABSTRACT

This study investigated the effects of prospective-user factors and five cognitive sign features on guessability of safety signs. Sixty Hong Kong Chinese subjects guessed the meanings and rated the sign features of 63 Mainland China safety signs. The prospective-user factors of working or site visit experience at laboratory or construction site, awareness of safety signs in daily life, injury experience due to ignorance of safety signs, and driving experience had significant effects on guessing performance. However, gender, Mainland China visit experience, and family member working at laboratory or construction site had no influence on guessing performance. The guessability scores varied with the five cognitive sign features viz. familiarity, concreteness, simplicity, meaningfulness, and semantic closeness. The guessability of safety signs was better when the signs were familiar, concrete, simple and meaningful and when the signs were associated with the underlying concepts. Overall, the findings showed that prospective-user factors and cognitive sign features are involved in effective communication of safety sign messages.

Relevance to industry: Posting of safety signs is a possible safety precaution measure that can be taken to attempt to reduce accidents and injuries in industrial undertakings. The findings of this study provide useful information for designing more user-friendly safety signs which could act as a reference for interface designers to develop more user-friendly safety signs in the future.

1. Introduction

In a statistical analysis of industrial accidents, Liu et al. (2005a) found that the death toll in China rose continuously from 2000 onward. There are many possible safety precaution measures that can be taken to attempt to reduce accidents and injuries in industrial undertakings. Important among these measures is the posting of safety signs. The National Standard on Safety Signs in China was established to alert Chinese workers to unsafe conditions in the workplace (GB 2894, 1996). It consists of 66 safety signs that are classified into prohibition, warning, mandatory and guide categories. Ten of these 66 safety signs are extracted from the International Standard, ISO 3864. Safety signs in the International Standard are categorized according to the function viz. escape and emergency equipment, fire safety, mandatory action, prohibition, and warning with the use of geometric shapes and colours (ISO 3864-3, 2006). In the American National Standard, safety symbols usually consist of a black image on a white background and surround shapes are required for the safety alert and prohibition symbols (ANSI Z535.3, 2002). The International Organization for Standardization (ISO 3864-3) and the American National Standards Institute (ANSI Z535.3) recommend that signs and symbols must reach a criterion level of at least 67% and 85% correct, respectively, in a comprehension test to be considered acceptable. In a study investigating comprehension of a broad range of safety signs, Duarte and Rebelo (2005) found that the comprehension levels of most safety signs do not reach the ANSI or ISO comprehension criteria. Liu et al. (2005b) evaluated 16 safety related symbols used on intensive care unit devices in Germany and China, and found that only eight symbols used in Germany and four used in China reached a comprehension score higher than the 67% acceptance criterion of ISO 3864-3. In both Germany and China, only three symbols reached the 85% criterion specified by ANSI Z535.3. These two studies on safety signs show that there are considerable problems associated with usability and some signs do not convey safety messages effectively. The idea of design as communication for making a given design easy to understand and interpret is well known (Redström, 2006). It is important that 'the industrial designer should make a sign as clear and unequivocal as possible so that the target group understand the message' (Mono, 1997, p.51).

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Failure to achieve adequate understanding and to convey warning information effectively can lead to injury or death (Lesch, 2003).

The International Organization for Standardization defined usability as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use' (ISO 9241-11, 1998). In relation to usability-based approaches to product design, Jordan (1998) identified five distinct components, namely; guessability, learnability, experienced user performance, re-usability, and system potential; that influence the usability of a product. Guessability is a measure of the cost (e.g. in terms of time on task or errors made) to the user of a product when performing a task for the first time; the higher the guessability, the lower the cost. The learnability component is concerned with the cost to the user in achieving some competent level of performance on a task with a product, while the experienced user performance is the relatively stable performance level that an experienced product user reaches. The system potential component represents the theoretical optimal performance obtainable with a product with respect to a particular task, and the re-usability refers to the performance level achieved when a user returns to a task with a product after an extended period of non-use. For safety signs, studies have been reported on, for instance, sign noticeability (Davies et al., 1998), font size and message layout (Rogers, et al., 2000), sign training (Brelsford et al., 2001; Goonetilleke et al., 2001; Wang and Chi, 2003), sign comprehensibility (Hancock et al., 2004), sign legibility (Shieh and Huang, 2004; Xie et al., 2007), cultural difference (Piamonte et al., 2001; Lesch et al., 2009; Chan et al., 2009), and the role of pictorials in signs (Young, 2001). However, there have been no investigations reported on the five important components of usability of safety signs which can critically affect human safety.

According to McDougall et al. (1999), in addition to the considerations of sign features that are self-evident (e.g. colour and shape) or those that can be identified only in relation to other signs (e.g. distinctiveness), sign features like familiarity, concreteness, complexity, meaningfulness, and semantic distance are of the central concern in sign research. Familiarity is the frequency with which signs have been encountered. Signs are concrete if they depict objects which have obvious connections with the real world while abstract signs do not. Signs are regarded as complex if they contain a lot of detail or are intricate, and simple if they only contain few elements or little detail. Meaningfulness refers, rather obviously, to how meaningful people perceive signs to be. Semantic distance is the closeness of the relationship between what is depicted on a sign and what it is intended to represent. Later, these five features are called cognitive sign features as they relate to people's perception and cognition (Ng and Chan, 2009). It is obvious that the success of effective communication of sign messages to users not only relates to user demographics but also to the five sign features. However, so far there has been no report of a detailed analysis and quantification of the five cognitive design features for industrial safety signs.

In view of the possibility of improving sign usability through exploring the components of product usability and cognitive sign features, the study reported here focused on investigating the relationships between sign features and the guessing performance of people who will use the signs i.e. prospective-users. In the type of task used in the experiment here, the act of guessing involves giving 'an answer, form an opinion or make a statement about something without calculating or measuring and without definite knowledge' (Li, 1999). There were eight prospective-user factors used in this experiment and apart from gender they involved previous experiences of the participants as follows: 'working at laboratory or construction site'; 'laboratory or construction site visit in past 12 months'; 'awareness of safety signs in daily life'; 'family member working at laboratory or construction site'; 'injury experience due to ignorance of safety signs in past 12 months'; 'Mainland China visit experience in past 12 months'; and, 'driving experience'. For the gender factor, previous research found that males had significantly better sign understanding than females, probably confounding with the effect of education level (Al-Madani and Al-Janahi, 2002). By controlling for the education factor in this study, it was expected that males and females would have similar guessing performance levels on industrial safety signs. People with laboratory or construction site visit or work experience are usually more familiar with the context for safety signs. It has been shown that the context i.e. the potential locations where the signs might be viewed increased symbol comprehension (Wolff, 1995; Wolff and Wogalter, 1998). Therefore, it was hypothesized that safety sign guessing performance would relate to 'working experience at laboratory or construction site' and 'laboratory or construction site visit experience'. In accordance with the communication-human information processing model, warning information attended to by a receiver could move forward to the subsequent information processing stages such as comprehension (Wogalter et al., 1999). It was thus expected that safety sign guessing performance would improve with 'awareness of safety signs in daily life'. People with 'family member working at laboratory of construction site' are probably more aware of safety signs and hence would perform better in guessing. Similarly, people with 'injury experience due to ignorance of safety signs' probably have better awareness of safety signs and therefore would have better guessing performance on the signs. Understanding other people's cultures, societies and political systems are of great value to travellers. Improved ability to guess the meaning of Mainland China safety signs was therefore expected for subjects who had 'Mainland China visit experience' recently. Traffic sign learning and testing procedure may have some transfer effects for the licensed drivers, thus better guessing performance for industrial safety signs was expected from those with driving experience. Regarding the relationship between sign guessability and the five sign features, it was expected that prospective-users will guess signs better if the signs are familiar to them. As concrete signs provide a direct visualization aid in helping subjects to elicit the meaning, they were expected to have higher guessability scores than abstract ones. Extraneous decorative parts on signs could confound understanding of the signs (Bruyas et al., 1998), so it was hypothesized that simple signs will be easier to guess than complex ones. The meaningfulness of a stimulus depends on its associated imagery and refers to the ability with which a stimulus can elicit a meaning in one's mind (Preece et al., 1994). Hence, better guessing ability was expected for meaningful signs. For semantic closeness, signs that are perceived to be associated with a concept were expected to lead to higher guessability scores. In summary, guessability was expected to be higher for familiar signs, concrete signs, simple signs, meaningful signs, and for signs with higher semantic closeness ratings. The results of this study should provide useful information for designing more user-friendly safety signs.

2. Method

A questionnaire was developed for the study in order to capture the following information from the subjects: colour vision status; demographics and prospective-user factors; sign guessing scores; and, ratings on sign features.

2.1. Subjects

Thirty male and thirty female Hong Kong Chinese subjects with tertiary level education voluntarily participated in this study. Their ages ranged from 20 to 35 years (median = 25 years). None of the