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Effects of user factors and sign referent characteristics in participatory construction safety sign redesign

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ABSTRACT

This study examined the effects of user factors and sign referent characteristics in participatory construction safety sign redesign. A group of Hong Kong Chinese construction workers were requested to draw different safety sign referents and then to narrate their drawings and redesign ideas. The more concrete the sign referents (i.e. referents that represent an actual substance or thing), the higher the success at producing pictorials and the greater the commonality between redesign suggestions for the referents. Construction workers with lower education level perceived the referents as less concrete than those with higher education level; and those with higher spatial imagery preference (i.e. the preference for using imagery to represent spatial relations among objects schematically and to perform complex spatial transformations) were better at processing unfamiliar and abstract referents. However, construction workers were not aware of and did not understand the intended meanings of particular surround shapes and colors commonly used in safety sign systems. These findings are useful in facilitating the process and practice of participatory safety sign redesign with workers in future.

1. Introduction

There has been a growing concern about construction safety in Hong Kong in recent years. The construction industry in Hong Kong has been recorded as having the highest number of fatalities and highest accident rate among all industry sectors for seven consecutive years (Hong Kong Labour Department, 2013a). Also, there were 3160 industrial accidents in the construction industry in 2012, higher than the average for the past five years (2006–2011) by 5.7%; the accident rate and industrial fatality rate per 1000 workers for the construction industry in the same year was 0.443 and 0.337, respectively (Hong Kong Labour Department, 2013b). The Pay for Safety Scheme has been introduced by the Government to the public works construction contracts in order to uplift their safety performance in Hong Kong, and the potential benefits in implementing such scheme has recently been explored (Choi et al., 2011). There are other possible safety precaution measures that can be taken to attempt to reduce accidents and injuries in workplaces. Provision of safety signs is one of the significant safety precaution measures that can be implemented quickly to attempt of reducing risks. The Construction Site Safety Handbook published by The Real Estate Developers Association of Hong Kong and The Hong Kong Construction Association (2005) specified that provision of suitable and relevant safety signs is one of the practical guidance measures that can be taken to manage safety and health risks on construction sites. According to Hong Kong Government Development Bureau's (2008) Construction Site Safety Manual, the display of safety signs is one of the methods of promoting and maintaining safety awareness and developing a safety and health culture amongst all persons on the site. The safety signs are usually used to represent a hazardous situation, indicate the result of not avoiding a hazard, describe safety precautions, advise construction workers of the evasive actions to take, or to provide other directions to eliminate or reduce hazards within a context.

Few research studies have investigated the comprehension ability of construction personnel regarding safety signs used on construction sites. Arphorn et al. (2003) found that a majority of the construction workers could not deduce the relevant information from existing safety signs in Thailand. In Hong Kong, Tam et al. (2003) showed that construction personnel have substantial problems in comprehending the safety signs that are posted on construction sites. They recommended that the signs be redesigned so as to improve the effectiveness of sign and the safety message conveyed. Kim et al. (2013) analyzed construction worker awareness of and understanding of safety signs in Gyeonggi-do, Korea and revealed an urgent need for education on construction safety signs. Hare et al. (2013) examined the effectiveness of pictorial aids for communicating hazards and controls to migrant workers on

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construction sites in the U.K., and the results showed that twenty-three out of 118 images failed to reach the ANSI threshold of 85% correct interpretations and therefore needed to be altered.

Comprehensive research studies on effective methods of safety sign training have been reported in recent years (Chan and Ng, 2010; Lesch, 2008; Lesch et al., 2011; Ng and Chan, 2008). However, when it is not possible to significantly improve comprehension of graphic signs after training, redesign of signs becomes necessary (Chan and Ng, 2010; Ou and Liu, 2012). Some research studies have suggested as to when and how sign redesign should be carried out (Akella, 2009; Chan and Chan, 2011; Duarte et al., 2014; Mayhorn et al., 2004; Ng and Chan, 2013; Nivala and Sarjakoski, 2005). Nivala and Sarjakoski (2005) specified that symbols which were interpreted as having several different meanings must be redesigned. Mayhorn et al. (2004) indicated that symbols which did not reach a satisfactory level of comprehension should be redesigned. Chan and Chan (2011) recommended that redesigned safety signs need to be developed with consideration given to the cognitive sign features of familiarity, concreteness, simplicity, and meaningfulness. Duarte et al. (2014) found that symbol-based signs with some weaknesses in areas such as familiarity, legibility, and depiction quality need to be redesigned.

The proposed strategies of Mayhorn et al. (2004) and Chan and Chan (2011) on sign redesign were mainly based on the consideration of user perceptions and evaluation feedback. There is a need to involve the ideas of users to create successful human factors and ergonomics designs. In order to better address user needs and preferences, an increasing focus has been put on the integration and involvement of users in the design process (Broberg et al., 2011; Demirbilek and Demirkan, 2004; Vink et al., 2006). With user participation in the process of graphic sign design, the signs will be more likely to be correctly interpreted as having the intended meanings because they were more likely to directly map onto the mental models of users (Kowalewski et al., 2013; Ziefle et al., 2008). One of the user-involved design methods for graphic sign design is called stereotype production method (Arning and Ziefle, 2009; Batu Salman et al., 2010; Duarte et al., 2009; Kowalewski et al., 2013; Macbeth et al., 2000; Ng et al., 2012, 2013; Ziefle et al., 2007, 2008). The stereotype production method, also known as the sign production method, requires a group of representative users to draw pictorials that best express the sign referent of interest, i.e. the message that a sign is intended to convey. The population stereotype, which is the most common pictorial element generated for the referent, is then passed to graphic designers to render into an actual sign.

Literat (2013) suggested that drawings are able to craft a more complete depiction for abstract notions and spatial relations among objects in pictorial form that would be difficult or impossible to express via writing or speech. In a usability evaluation test conducted by Nivala and Sarjakoski (2005), for some symbols which were not easy to comprehend, users gave examples of better symbols by drawing their ideas out proactively. To ease the challenge of mis- and over-interpreting the drawings, researchers should let the participants narrate their own drawings (Literat, 2013). This tactic enables the participants to be in charge of the interpretation process and is a recommended means of data triangulation. Ng et al. (2011) observed that users would like to have a subsequent discussion of their drawings for each sign referent with design facilitator, and such verbal discussion could enhance the validity of the content of the drawings for sign representation. It was recommended that users shall not only be asked to draw pictorials to visually represent the sign referent but also be provided an opportunity to talk about their own drawings i.e. draw-and-tell.

There is not much research exploring the usage of draw-and-tell method for user participation design (e.g. Chamorro-Koc et al., 2008; Guha et al., 2005). In the development of new technology centers for children, the child users were invited to draw their individual ideas about improving centers and then, based on their drawings, to explain their ideas to facilitators (Guha et al., 2005). To further improve current products such as barbeque grills, blenders, and grass shears, Chamorro-Koc et al. (2008) asked product users to draw out their ideal designs on papers and then verbally describe the information conveyed in their drawings. Research studies on participatory construction safety sign or other safety sign design or redesign with draw-and-tell, however, have never been attempted. The participation of employees in ergonomics analysis and design for safety concerns, hazard management and workplace redesign are generally beneficial to both the organization and the employees (Matthews et al., 2011).

This study was conceived and designed to increase understanding of the effects of user factors and sign referents on participatory safety sign redesign process among construction workers using the draw-and-tell method. The results should help in the optimization of participatory safety sign redesign through draw-and-tell, and thus facilitate the process and practice of sign redesign with workers involvement in future.

2. Method

User factors such as age group, education level, years of working experience in the construction industry, vividness of visual imagery, object imagery preference and spatial imagery preference; and referent characteristics such as familiarity, concreteness, ease of visualization and context availability were examined in this study. Referent familiarity means the perceived frequency with which a sign referent has been seen before. Ease of visualization refers to the ease of forming a visual mental picture of a sign referent. Concrete referents represent an actual substance or thing, whereas abstract referents denote something apart from some material or object basis. High context availability refers to the situation where people can easily associate a sign referent with a certain context or circumstance in which the referent would appear; otherwise, the referent is said to be low context availability. A group of Hong Kong Chinese construction workers were asked to draw different safety sign referents and were then asked to narrate their drawings and redesign ideas. The drawings for each sign referent and the user and referent effects in sign redesign were assessed.

2.1. Participants

Twenty-three Hong Kong Chinese male construction workers participated in the study. The ages of the participants were between 18 and 59 years, with a mean age of 31.5 years, and a standard deviation of 8.5 years. There were site laborers (30%), bricklayers (17%), inspectors of works (13%), plant and equipment operators (9%), concreters (9%), excavators (4%), carpenters (4%), bamboo scaffolders (4%), electrical fitters (4%), and welders (4%), all working in the construction industry at the time of the study. Each participant signed a written informed consent at the beginning of the study.

2.2. Referents

In a previous study Chan and Chan (2011) on commonly used Hong Kong industrial safety signs, it was found that 24 industrial safety signs were comprehended at a level of less than 75%. Half of these sign referents were randomly selected and used for experimentation in this study (Table 1).

2.3. Apparatus

A touch screen tablet personal computer with dual core 1 GHz processor and 7-inch monitor (Samsung GALAXY TAB 2.7.0) was