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Comprehension of safety pictograms affixed to agricultural machinery: A survey of users

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ABSTRACT

Introduction: Pictograms affixed to agricultural machinery are important tools to reduce the occurrence of accidents and injuries when correctly noticed, comprehended, and followed. This study investigated the knowledge of safety pictograms used in agricultural machinery in a sample of farmers and farm workers and examined the factors influencing their comprehension. *Method*: A questionnaire with 12 safety pictograms used for agricultural machinery was administered to 281 owners or users of agricultural machinery. For each of the pictograms, the participants had to select the most appropriate verbal description from among four choices. *Results*: The pictograms examined yielded poor comprehension scores, including warnings related to the most frequent accidents involving agricultural machinery. Familiarity with the pictograms and years of experience with agricultural machinery significantly increased users' comprehension of the meaning of the pictograms. *Conclusions*: Specific training programs should be designed to draw attention to safety pictograms and to instill their meaning.

1. Introduction

Pictograms are graphical, non-verbal symbols that are being used to convey safety information. They have a twofold purpose: to communicate an existing hazard and "*to change behavior, that is, to redirect people away from performing unsafe acts that they might otherwise perform*" (Wogalter & Laughery, 1996, p. 33); they can also increase an individual's awareness of risks by providing an instantaneous memorandum of the risk (Laughery, 2006). Benefits of pictograms arise for a number of reasons: they can be better remembered than words and can quickly communicate concepts and instructions, avoiding problems due to impairment in reading skills (e.g., children, the elderly, and the illiterate) or to unfamiliarity with the language used in the message (e.g., foreigners; Lesch, 2003; Wogalter, Conzola, & Smith-Jackson, 2002; Wogalter & Laughery, 1996; Wogalter, Silver, Leonard, & Zaikina, 2006; Wogalter, Sojourner, & Brelsford, 1997; and Young & Wogalter, 2000). In particular, Boelhouwer, Davis, Franco-Watkins, Dorris, and Lungu (2013) showed that the addition of pictograms to safety data sheets and product labels may improve the communication of safety information for both naïve and expert users. Dowse and Ehlers (2005) found that incorporating pictograms on medicine labels contribute positively to both understanding and adherence to safety rules, and in their study on pharmaceutical labels, Kalsher, Wogalter, and Racicot (1996) found that both undergraduates and older adults preferred labels with pictograms.

However, different studies have reported that many pictograms currently in use are poorly understood (Duarte & Rebelo, 2005; Liu, Zhong, & Xing, 2005; Rubbiani, 2010). For example, Dowse and Ehlers (2001) investigated the interpretation of pharmaceutical pictograms in a group of low-literate participants and found low comprehension rates for most of the pictograms. Rother (2008) obtained similar results when investigating the interpretation of pesticide labels' pictograms among farm workers, and Chan and Ng (2010a) reported that many of the 63 industrial safety pictograms considered in their study were not successfully guessed.

1.1. Factors influencing comprehension of pictograms

Different characteristics of the intended target audience and of the pictogram itself can affect pictogram comprehension (for a review, see Rogers, Lamson, & Rousseau, 2000). For example, users' age and cultural background (Blees & Mak, 2012; Ng & Chan, 2007; Rother, 2008; Smith-Jackson & Essuman-Johnson, 2002; Smith-Jackson, Wogalter, & Quintela, 2010) are significant predictors of their ability to comprehend the meaning of the pictograms. Some contrasting results are reported about age and education: some studies showed better comprehension in younger (Hancock, Fisk, & Rogers, 2005; Lesch, 2003) and more educated people (Ng & Chan, 2008) while other studies reported no effect of these two variables (see Ng & Chan, 2008 for age and Rubbiani, 2010 for both age and education). Considering the intrinsic characteristics of the pictogram, some aspects such as familiarity, concreteness, simplicity and accuracy of semantic depiction (Liu & Ho, 2012; Wang & Chi, 2003) are closely related to comprehension scores. In particular, inconsistent results are reported in the literature regarding the role played by

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familiarity (i.e., prior experience with a warning or a product; for a review, see Rogers et al., 2000). On one hand, some studies have shown that familiarity with a pictogram had no effect on the likelihood of comprehending its meaning (Chan & Ng, 2010b; Ng & Chan, 2011), but, on the other hand, other studies have shown a significant and positive effect of familiarity on comprehension scores yielded by pictograms (Chan & Ng, 2010a; Hancock, Rogers, Schroeder, & Fisk, 2004; Ng & Chan, 2007, 2008).

Another relevant factor that can affect comprehension is visibility of the pictogram. Poor noticeability due to inadequate placement (Davies, Haines, Norris, & Wilson, 1998) or to damage by sudden or gradual natural conditions (e.g., weather) or human actions (Ng & Chan, 2013) can cause pictograms to fail to convey information.

Finally, a factor that is considered important to improve pictograms' comprehension is training (Hara et al., 2007). Yet here, empirical evidence also offers inconsistent results about the effects of training (Brahm & Singer, 2013). Some studies have shown that training led to a significant improvement in comprehension that was relatively stable over time (Dowse & Ehlers, 2001; Wogalter et al., 1997) and it improved accuracy and speed of responding for both younger and older participants (Lesch, 2003, 2008). On the other hand, some other studies have shown that only recall training was effective (Chan & Ng, 2010b) and that there was a significant decline in comprehension performance in a post-training phase (Joshi & Kothiyal, 2011; Wang & Chi, 2003).

1.2. Pictograms and agricultural machinery

Agriculture is one of the three most hazardous sectors in the developing and industrialized countries, together with the mining and construction industries (ILO, 2000, 2014). In several European countries and in the United States, the rate of fatal accidents in agriculture is double the average number for all other industries (Forastieri, 2001). Out of some 335,000 fatal workplace accidents worldwide, approximately 170,000 occur among agricultural workers (ILO, 2014). In addition, agriculture is characterized by an increasing number of older workers (McLaughlin & Mayhorn, 2011, 2014; McLaughlin & Sprufera, 2011). The ability of aging farmers to avoid injury is greatly affected by the age-related health issues (Heaton, Azuero, Phillips, Pickens, & Reed, 2012), thus the rate and severity of injuries in agriculture are expected to be further elevated (Myers, Layne, & Marsh, 2009). The high risk of fatal or non-fatal injuries comes from the fact that farmers and farm workers operate potentially dangerous machinery, vehicles, and chemicals.

The relevance of pictograms for safety in agriculture is mainly investigated with regard to pesticides (for a review, see Emery et al., 2014), even though machinery is the major source of injury (Douphrate, Rosecrance, Reynolds, Stallones, & Gilkey, 2009; Forastieri, 2001; Jawa et al., 2013; Narasimhan et al., 2010). Tractors, in particular, are involved in the highest number of fatalities. Carlson et al. (2005) reported that there are 9.6 tractor-related injuries/1000 persons/year, and tractor rollover is the leading cause of death for farmers and farm workers (Cavallo et al., 2014a, 2014b; Cavallo, Görücü and Murphy, 2014; Cavallo, Langle et al., 2014).

To ensure the health and safety of workers and consumers, a safety hierarchy protocol (Caputo, Pelagagge, & Salini, 2013; Murphy & Anderson, 1992; Purschwitz, 2006) should be applied to the design of machinery and equipment. This protocol consists of a three-step procedure: (a) eliminating hazards/reducing risks by design, (b) adopting technical protective measures when hazards cannot be eliminated, and (c) informing users through symbols or pictograms that give information about residual risks that could not be eliminated by machine design. To promote the use of safety pictograms on agricultural machinery, the International Organization for Standardization published the ISO 11684:1995 standard, establishing some principles for the design and application of safety signs and pictograms on machinery for agriculture and forestry. The scope of the standard is to warn operators and other exposed individuals about machinery's residual risks. The standard outlines the objectives of safety signs, describes the basic safety sign formats and colors, and provides guidance on developing a safety sign. In addition, the standard discriminates between (a) hazard description pictorials, which present a visual description of the hazard and the consequences of not avoiding it, and (b) hazard avoidance pictorials, which present visual instructions on how the hazard should be avoided. The standard provides, in Annexes A and B, over one hundred examples of hazard description pictorials in over 10 categories (e.g., entanglement hazards and cutting hazards) and hazard avoidance pictorials.

Because there is frequently insufficient space to place all necessary warnings, usually text messages explaining the pictograms are relegated to the operator's manual (Cowley & Wogalter, 2011; Tebeaux, 2010a; Young & Wogalter, 1990). The operator's manual is usually considered the complete reference source for a safe machine's operation and maintenance, (ISO 3600:1996). However, the automotive literature shows that operator's manuals are infrequently or incompletely read by consumers (Leonard, 2001; Mehlenbacher, Wogalter, & Laughery, 2002). Similarly, recent studies related to agricultural machinery have shown that tractor users do not read the operator's manual until an accident occurs (Tebeaux, 2010a). The excessive information content, the confusing visuals and safety icons used, and the poor document design discourage readers rather than clarifying critical information (Tebeaux, 2010b).

Finally, Field and Tormoehlen (2006) highlighted the importance of education and training as intervention strategies to promote health and safety in agriculture. This perspective seems to be shared by the governments and other relevant institutions: most developed countries, such as United States, Australia, New Zealand, and the European Union countries, allocate several resources for agricultural and forestry safety education (European Commission, 2011; Murphy & Lee, 2009). However, specific and standardized training about safety warnings seems to be lacking because, as reported by Tebeaux (2010a, p. 24), "*farm safety and health educators have not had a comprehensive, easy to understand, and standardized tool to use as a guide in their work.*"

1.3. Aims of the present study

Pictograms affixed to agricultural machinery are important tools to warn the user about the risks that can arise from the intended use or any foreseeable misuse of the machine, so that he or she can adopt protective measures and safety behaviors (Fraser, 2009; ISO 14121-1:2007). However, to our knowledge, no studies have investigated the comprehensibility of these pictograms among the agricultural population.

The study was addressed to investigate in a sample of Italian actual users of agricultural machinery:

- the comprehension scores of pictograms affixed on agricultural machinery and reported in operator's manuals;
- which of the pictograms investigated in the study are the most and the least comprehended, with regard to the type of hazards they are warning about; and
- which factors of those included in the study (e.g., age, education, and previous exposure), affect pictograms' comprehension.

The study offers a novel contribution to safety signs knowledge in the agricultural sector because knowledge and comprehension of pictograms in the agricultural industry are usually investigated only with regard to pesticides. In addition, the study involved a sample of real users, for whom safety issues are more critical. Finally, the study considered pictograms only, with no text messages attached, to investigate what the graphical symbol would communicate to users without any wording cues.