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**Comprehension rates of safety pictorials affixed to agricultural machinery among Pennsylvania rural population**

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# UNIVERSITÀ DEGLI STUDI DI TORINO

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1 RUNNING HEAD: Comprehension of safety pictorials affixed to agricultural machinery  
2 among Pennsylvania users

3

## 4 **Comprehension rates of safety pictorials affixed to agricultural** 5 **machinery among Pennsylvania rural population**

6

### 7 ABSTRACT

8 Pictorials affixed to agricultural machinery are important tools to warn the user  
9 about the risks that can arise from the intended use or any foreseeable misuse of the  
10 machine; however, in the U.S. there is no legal requirement regarding the adoption of  
11 safety pictorials on agricultural machinery. This study investigated comprehension of  
12 safety pictorials in a sample of U.S. agricultural machinery users. Two hundred and  
13 eight Pennsylvanian participants were asked to indicate the meaning of 12 frequent  
14 safety pictorials by choosing one among 4 alternative labels. The results showed that  
15 pictorials referring to the most common risks in agriculture were not necessarily the best  
16 comprehended images, and two out of five participants have never seen the pictorials  
17 included in the study. Years of experience with the machinery enhanced  
18 comprehension, whereas ‘part-time’ farming and occasional use of machinery were  
19 related to poorer comprehension. Implications for operators’ safety and solutions to  
20 improve pictorial noticeability and comprehension are discussed.

21 KEYWORDS: Agricultural machinery; Hazard communication; Pictorial  
22 comprehension; Occupational safety; Warning.

### 23 **1. Introduction**

1           Visuals have been used by humans to communicate since the earliest paintings were  
2 made on cave walls. The bridge between historical and modern pictorials is the social scientist  
3 Otto Neurath, who in 1925 created the Isotypes, a way to represent information by means of  
4 easily interpretable icons. From the beginning, Neurath's pictorials have been used to  
5 communicate information about the working environment, such as production process,  
6 emigration, mortality and unemployment. A contemporary successful example form of visual  
7 communication are the emoticons, which were created in 1982 by scientist Scott Falham.  
8 Thanks to pervasive mobile communication devices, emoticons are today universally and  
9 globally adopted (see Holmes, 2013, for a short but complete review of non-verbal symbols'  
10 evolution).

11           Modern pictorials are used and have been investigated in many different domains,  
12 such as pharmaceuticals, heavy industry, transport and consumer goods (Barros et al., 2014;  
13 Boelhouwer et al., 2013; Erdinc, 2010; Ng and Chan, 2008). Typically, pictorials are used to  
14 convey safety information, since they can quickly communicate concepts and instructions and  
15 can be better remembered than words (Laughery and Wogalter, 2014; Wogalter et al., 2006).  
16 Since a pictorial is supposed to be immediately comprehended by everyone without any  
17 associated words and without any specific education (Adams et al., 2010), different standards  
18 have been developed (e.g., those from the ANSI Z535 Committee on Safety Signs and Colors)  
19 to promote the adoption and use of uniform and effective symbols for safety communication,  
20 providing some procedures for evaluating image effectiveness in communicating the intended  
21 message, together with considerations for graphic design (ISO-7010:2011; ANSI Z535.3-  
22 2011). Despite all these efforts, different studies have reported that many pictorials currently  
23 in use are poorly understood (Chan and Ng, 2010a; Duarte et al., 2014; Liu et al., 2005;  
24 Rubbiani, 2010). Furthermore, inconsistent results are reported in the literature about the role  
25 played by socio-demographic variables and previous experience (i.e., familiarity) with the

1 pictorials in affecting users' comprehension rates (for instance, see Lesch, 2003, and Ng and  
2 Chan, 2008 for age; Ng and Chan, 2011, and Hancock et al., 2004 for familiarity with the  
3 symbols).

4 Warning users against potential hazards is an even more relevant issue in agriculture,  
5 as this is one of the three most hazardous sectors in developing and industrialized countries  
6 (ILO, 2014). Kumar and Dewangan (2009) reported 6.39 accident per 1000 workers/year in  
7 north eastern India; Kogler et al. (2015) reported that in the year 2013, 3,805 accidents  
8 occurred in the entire agricultural sector in Austria, and 56 of them were fatal; Fabiano et al.  
9 (1995) in their analysis of accidents in the Italian industry in the century 1890-1989,  
10 highlighted that despite the considerable variations of economic and social conditions and the  
11 increasing technological and scientific improvement, the number of accidents never dropped  
12 below 110 cases per 1000 workers/year, with agriculture being the most critical sector. For  
13 the U.S., the fatal work injury rate for the agriculture, forestry, fishing and hunting sector was  
14 24.9 (per 100,000 full-time equivalent workers) in 2014, whereas the fatality rate for all the  
15 occupational sectors in the same year was 3.3 (NIOSH, 2016; U.S. Department of Labor  
16 2016a, 2016b).

17 Agriculture involves the use of a wide variety of hazardous equipment and instruments  
18 engendering many risks for the users, and machinery is, indeed, the major source of injury  
19 (Jawa et al., 2013). In the study by Kumar and Dewangan (2009), farm implement-related  
20 accidents accounted for 40% of the accidents, and Kogler et al. (2015) noted that in the period  
21 2008-2010, 59% out of 3.250 accidents in Austria were caused by machinery.

22 The most hazardous machinery in agriculture is the tractor (Jawa et al., 2013) and the  
23 most serious accidents are due to overturn or rollover. An important role in reducing the  
24 likelihood of tractor operators from being crushed in such events is the adoption of Roll-over  
25 Protective Structure (ROPS) (Cavallo et al., 2014; Murphy et al., 2010). The U.S.

1 Occupational Safety and Health Act (OSHA) requires approved ROPS to be present on  
2 agricultural tractors over 20 horsepower (15 kW) manufactured after October 25, 1976, when  
3 operated by hired employees (Murphy, 2014). OSHA regulations cannot be enforced on farms  
4 with fewer than 11 employees, and a farm operator who has no employees is not affected at  
5 all by any OSHA regulation. This legally allows employers and other farm operators in U.S.  
6 to avoid the use of ROPS on a large number of tractors.

7 Other machinery such as harrows, seeding equipment, harvesters, mowers, wagons,  
8 trailers, manure spreaders, and elevating equipment are reported as hazardous and associated  
9 with high rates of injuries and deaths in the sector (ILO, 2011). The principal safety hazards  
10 related to these machineries are cutters, gears, belts, shafts and other moving parts, burst  
11 hydraulic hoses and live electrical equipment, which may cause cuts, burns, electrocution,  
12 fractures and amputations. Such injuries occur both during the course of production and also  
13 during maintenance and repairs, cleaning, clearing blockages, etc. (ILO, 2011; Kumar and  
14 Dewangan, 2009; Narasimhan et al., 2010).

15 To promote users' safety and health, the International Labour Organization (ILO,  
16 2011) recommends the use of safety pictorials on agricultural machinery to warn the user  
17 about the risks that can arise from the intended use or any foreseeable misuse of the machine,  
18 allowing the user to adopt protective measures and safety behaviours (ISO 14121-1:2007).  
19 The International Organization for Standardization establishes some principles for the design  
20 and application of these safety pictorials. The standard dealing with the topic is the ISO  
21 11684:1995. It was developed based on ASAE S441.3 and since 2011, has been adopted as  
22 ANSI/ASABE AD11684:1995 (Apr 2011) by the American National Standard Institute  
23 (ANSI) and the American Society of Agricultural and Biological Engineers (ASABE),  
24 replacing the previous standard. In the U.S. there is no legal or mandatory requirement by  
25 state or federal government about the adoption of warning pictorials on agricultural

1 machinery. However, the compliance to ISO and other industry safety standards is considered  
2 de facto as the manufacturer's 'minimum obligation', although product compliance with  
3 safety standards does not prevent an injured person from suing a manufacturer in the civil  
4 court system.

5 The existing lack of mandatory safety pictorial adoption in the U.S. makes its rural  
6 population –and that of Pennsylvania in particular, as will be discussed in the next paragraph–  
7 a relevant context in which to investigate the familiarity with and the comprehension of these  
8 safety symbols.

### 9 *1.1 U.S. and Pennsylvania: agricultural system, machinery and safety issues*

10 The U.S. is one of the major players in global agricultural business (FAO, 2015). In  
11 2014, 17.3 million full- and part-time jobs were related to agriculture and related industries,  
12 corresponding to approximately 9.3% of total U.S. employment (USDA ERS, 2016). Every  
13 day, hundreds of U.S. agricultural workers suffer a serious lost-time injury (NIOSH, 2015),  
14 and according to statistics, 5% of these injuries result in permanent impairment (U.S.  
15 Department of Labor, 2016a). Deaths and injuries among the agriculture workforce have  
16 important economic consequences, such as medical costs and lost productivity and earnings;  
17 the cost of agricultural occupational injuries has been estimated to exceed \$4 billion in direct  
18 and indirect costs (NIOSH, 2011). Furthermore, fatal accidents in family owned farms,  
19 representing 97% of the U.S. farms (USDA, 2015), frequently lead the farms to halt  
20 operations and the survivors to leave the farms (Kelsey, 1991).

21 Within the U.S., agriculture represents a major industry in Pennsylvania. Indeed,  
22 Pennsylvania ranks first in mushrooms production, fourth in dairy, apple and grape  
23 production and horticulture retail sales, and seventh in winemaking (USDA, 2014a).  
24 The main data about farming systems, farm demographics and farm accidents in the U.S. and  
25 Pennsylvania is presented in Table 1. As can be observed, the Pennsylvanian local farming

1 system and rural population is a suitable representation of U.S. agriculture. Moreover, the  
2 main causes of accidents are similar for both U.S. and Pennsylvania, and in addition, the ratio  
3 between the number of deaths and the total number of operators is even higher in  
4 Pennsylvania than in the U.S. (0.0024 vs. 0.0018).

5 [Table 1 near here]

6 Based on these considerations, this study investigated the comprehension of safety  
7 pictorials affixed to agricultural machinery in a sample of Pennsylvania users. The aims were:

- 8 (1) to investigate comprehension rates of different pictorials and identify the most  
9 comprehended and the most critical (less comprehended) ones;
- 10 (2) to explore the familiarity (i.e., prior experience with a warning or a product; for a  
11 review, see Rogers et al., 2000) of the users with the safety pictorials;
- 12 (3) to evaluate which variables influence pictorials' comprehension, considering socio-  
13 demographic variables (education, age) and variables regarding participants' expertise  
14 (occupation, farm size, frequency of machinery use, years of experience with  
15 machinery).

## 16 **2. Method**

### 17 ***2.1 Participants***

18 The study was conducted interviewing visitors attending the 2014 edition of the 'Ag  
19 Progress Days', from August 12<sup>th</sup> to 14<sup>th</sup>. The 'Ag Progress Days' is Pennsylvania's largest  
20 outdoor agricultural exposition and features the latest technology and research exhibits,  
21 educational programs, and guided tours. The event is held at the Russel E. Larson Agricultural  
22 Research Center in Rock Spring, 15 km (9 miles) southwest of State College (PA), and it is  
23 sponsored by Penn State College of Agricultural Sciences. In 2014, according to the post-  
24 event figures (Penn State College of Agricultural Sciences, 2015), there were over 400

1 exhibitors from 34 states and 4 provinces of Canada and 42,000 attendees, over 60% of which  
2 were actively engaged in agriculture or related professions.

3         Similar to previous studies (Caffaro and Cavallo, 2015; Görücü, et al., 2014; Reichardt  
4 and Jürgens, 2009), we decided to take advantage of this high confluence of rural population  
5 in a single place to carry out the present research, as it is very hard to involve individuals from  
6 the agricultural population in face-to-face surveys, given they are spread across the country  
7 and have different paces of work.

8         The participants to the survey were asked to complete a paper-and-pencil  
9 questionnaire. The survey involved 245 individuals randomly selected during exhibition  
10 opening hours.

## 11         ***2.2 Instrument***

12         An adapted version of the questionnaire used by Caffaro and Cavallo (2015) and  
13 Caffaro, Mirisola et al. (2017) was administered in the present study. The questionnaire  
14 entails twelve pictorials from ISO 11684:1995 relating to the most serious risks in agriculture  
15 (ILO, 2011; Kumar and Dewangan, 2009; Narasimhan et al., 2010) (electrical hazards:  
16 Pictorial #5; crushing hazards: #1, #7, #12; cutting hazards: #4; entanglement hazards: #3, #6;  
17 stability hazards: #9, #11; maintenance hazards: #2, #8, #10). The pictorials were presented to  
18 the participants in a two-pictorial-panel format with a safety-alert symbol above and the  
19 hazard avoidance pictorial below. The participants in the survey had to select the most  
20 appropriate verbal description from among four choices to describe the meaning of each of  
21 the 12 pictorials included in the questionnaire. For each pictorial adopted for the study, there  
22 was a correct answer, a partially correct answer and two incorrect answers (see Chan and Ng,  
23 2010a, 2010b). Moreover, for each of the pictorials, the participants had to report whether  
24 they had already seen it (three alternatives: never, sometimes, often). Finally, the  
25 questionnaire included a section to collect some relevant socio-demographic information:

1 gender, age, state or county of origin, occupation, education, frequency of use of agricultural  
2 machinery, years of experience with agricultural machinery, type of machinery used, and the  
3 size of the farm where they usually work.

4 For each pictorial, correct answers were the description of the pictorial available in the  
5 ISO standard 11684:1995; the partially correct answers referred to an avoidance behaviour in  
6 relation to a partial identification of the hazard represented by the pictorial; incorrect answers  
7 referred to an avoidance behaviour which was not in relation to the specific hazard. The  
8 partially correct and incorrect answers were created as described in Caffaro and Cavallo  
9 (2015). These answers were also reviewed and approved by Penn State farm safety experts for  
10 use in Pennsylvania (the questionnaire used in the present study is reported in Appendix A).

### 11 **2.3 Procedure**

12 Participants were recruited from among the visitors of the exhibition. Trained research  
13 assistants handed out the questionnaire to people walking through the exhibition. The  
14 assistants explained the aims of the study and informed the participants that the questionnaire  
15 was anonymous. Pictorials were presented in a randomized order to each of the participants in  
16 the survey. Completion of the questionnaire took approximately 8 minutes. No incentive was  
17 offered to induce visitors to participate in the survey.

### 18 **2.4 Data analyses**

19 Data analyses involved three steps. First, for each pictorial included in the  
20 questionnaire, a comprehension score was calculated by following the dichotomous scoring  
21 procedure recommended in the ANSI Z535:2011 standard, i.e., scoring incorrect and missing  
22 answers as 0, and partially correct and correct answers as 1. Then, non-parametric Chi-  
23 squared tests were computed to assess whether the percentages of correct answers were not  
24 significantly inferior than the recommended comprehension rate of 85% or over (ISO  
25 7010:2011; ANSI Z535.3:2011).



1 correct answers were all significantly inferior than the minimum recommended  
2 comprehension rate of 85% (ISO-7010:2011; ANSI Z535.3-2011). Moreover, there is a huge  
3 variability among pictorials, the percentage of completely correct answers ranging from a  
4 minimum of 26.9% for pictorial #1 to a maximum of 78.4% for pictorial #9. When  
5 considering the sum of correct and partially correct answers, 5 out of 12 pictorials reached a  
6 percentage that is not significantly inferior than 85% (pictorials #2, #3, #4, #9, #11).

7 [Table 3 near here]

8 These comprehension rates seem not to be related to the familiarity with the pictorials  
9 studied (Table 4). In particular, the percentage of participants who have never seen a given  
10 pictorial ranged from a minimum of 21.6% for pictorial #6, a pictorial which showed a rather  
11 high percentage of incorrect answers (42.3%, Table 3), to a maximum of 58.7% for pictorial  
12 #7, which showed a rather low percentage of incorrect answers (22.1%). In fact, a Spearman's  
13 rank correlation showed that there was no significant relation between the familiarity with the  
14 pictograms and the comprehension rates ( $r_s(12) = -.123, p = .582$ ). Moreover, on average,  
15 approximately 40% of the participants have never seen the pictorials included in the study.

16 [Table 4 near here]

### 17 ***3.3 Effects of user characteristics on comprehension performance***

18 To determine the possible effects of some user characteristics on the comprehension  
19 performance, an ANCOVA was computed on the mean comprehension score obtained by  
20 each participant for the 5 pictograms that were recognized at an acceptable level (recognition  
21 rate not significantly inferior than 85%), by considering education, occupation, frequency of  
22 machinery use, and farm size as factors, and age and years of experience as covariates. The  
23 results showed a significant effect of years of experience,  $F(1, 181) = 3,92, p < .05, \eta p^2 =$   
24  $.021$ , and an interaction between occupation and frequency of machinery use,  $F(3, 181) =$   
25  $3,13, p < .05, \eta p^2 = .049$ . In more detail, the longer the experience with agricultural

1 machinery, the higher the comprehension score, ( $\beta = .003$ ,  $t(207) = 1.98$ ,  $p < .05$ ). Regarding  
2 the interaction between occupation and frequency of machinery use, univariate statistics  
3 revealed that part-time farmers who use agricultural machinery from time to time ( $EMM =$   
4  $0.787$ ,  $ESD = 0.068$ ) had significantly inferior comprehension scores than the ones who use  
5 machinery regularly ( $EMM = 0.982$ ,  $ESD = 0.067$ ); the frequency of machinery use had no  
6 effect on the comprehension scores for the other three types of agricultural operators.

#### 7 **4. Discussion**

8 This study investigated the comprehension of safety pictorials affixed to agricultural  
9 machinery in a sample of U.S. users. The ISO standard for safety signs (ISO 7010:2011) and  
10 the ANSI standard Z535.3 (2011) both require a symbol to reach a level of over 85% correct  
11 answers in an open-ended comprehension test to be considered acceptable. Similar to Davies  
12 et al. (1998), we adopted the 85% threshold of correct answers as a general guideline to  
13 examine the results of the pictorials' comprehension. Under this criterion, only 5 of the 12  
14 pictorials investigated obtained a satisfactory comprehension rate. In addition, the  
15 participants' comprehension performance presented a high variability between pictorials,  
16 supporting the idea that users comprehend the safety pictorials to some extent, but none have  
17 a complete and exhaustive knowledge of them.

18 The most comprehended pictorials were #4 and #9. Regarding pictorial #4 - referring  
19 to the risk of cutting or severing feet with moving knives when operating-, the Pennsylvania  
20 agricultural system is mostly geared towards forage crops for animal feeding (USDA, 2014a,  
21 2014b), where most of the farm tasks are carried out by machinery equipped with rotating  
22 knives/tools such as disc mowers, mower-conditioners and flail choppers for the fields, or  
23 feed mixer wagons in the animal raising facilities. Thus, the risk of being injured in the upper  
24 and lower limbs, or even worse, of being caught or pulled and killed by these tools, is well  
25 known among machine users in this area.

1           Regarding pictorial #9 referring to the need to lock ROPS in upright position, over the  
2 years, different approaches and strategies for increasing the number of ROPS on tractors in  
3 use in Pennsylvania have been adopted: educational programs, incentives for ROPS  
4 retrofitting or scrapping older farm tractors without ROPS, social marketing, and enacting  
5 state or national regulations that require tractors to be equipped with ROPS. All these actions  
6 have made farmers widely aware of the protection ensured by ROPS, and the popularity of  
7 ROPS on farm tractors has consistently increased up to 59% in 2006. This percentage,  
8 however, is not considered sufficient to reduce the overturn fatalities nearly to zero (Murphy  
9 et al., 2010).

10           The third most comprehended pictorial was #2, referring to the need to consult the  
11 operator's manual before performing maintenance activities on the machine. It is encouraging  
12 that this important pictorial was well comprehended, since almost 18% of injuries occur while  
13 performing maintenance and repair work (Narashiman et al., 2010). However, it has to be  
14 taken into account that the automotive literature shows that operator's manuals are  
15 infrequently or incompletely read by consumers (Mehlenbacher et al., 2002) due to the  
16 excessive information content, the confusing visuals and safety icons used, and the poor  
17 document design (Tebeaux, 2010). Thus, some changes in the design of the manuals should  
18 be made to encourage more frequent and complete reading. A way to make user manuals  
19 easier to read and follow – thus enhancing the relevance and noticeability of reported safety  
20 information - could be to transfer them into some digital devices. Currently, digitalisation is  
21 of broad interest in our society, with many applications in different life domains.

22           Technological interfaces could also be adopted for safety issues (Reinert, 2016); user manual  
23 layouts could be rearranged to fit into some apps for mobile phones or other multimodal  
24 interfaces and interactive devices on agricultural machines to improve users' attention  
25 towards as well as comprehension of safety information (Kohanbash et al., 2012).

1 Another well-comprehended pictorial was #11, referring to the risk of tractor roll-over  
2 on steep slopes. Roll-over is a well-known cause of death (Molari et al., 2014) and the high  
3 percentages of correct answers may be encouraging, suggesting that this pictorial leads to  
4 interpretations that may prevent hazardous behaviours. In addition, previous studies have  
5 shown that concreteness, meaningfulness and semantic closeness (Chan and Ng, 2010a,  
6 2010b) of a pictorial may increase its comprehensibility. This could be the case of pictorial  
7 #11, as it is highly concrete, reporting the hazardous agent (the slope) and the effects of  
8 driving on it (machine is rolling-over).

9 The last pictorial with an adequate comprehension rate was #3, referring to the risk of  
10 entanglement in the Power Take-Off (PTO) drive shaft. This result is encouraging since every  
11 tractor, which is the most commonly used agricultural machine (Iftikhar and Pedersen, 2011),  
12 is equipped with a PTO, and PTO drive shaft safe operation is one of the main topics in farm-  
13 machinery health and safety promotion campaigns (Thomas and Buckmaster, 2003).

14 Besides these 5 pictorials, for 7 out of 12 pictorials, the comprehension rates could not  
15 be considered as sufficient. These 7 pictorials referred to a variety of risks operators are  
16 exposed to: crushing, entanglement and electrical risks, and maintenance-related risks.

17 The pictorial showing the lowest comprehension rates was #1. The reason for this low  
18 rate may be that this pictorial is specific to some types of machines, namely those with lifting  
19 hydraulic cylinders, thus the users may not be familiar with it (actually 39.4% declared never  
20 having seen one). On the other hand, considering the pictorial characteristics that may affect  
21 comprehension (Liu and Ho, 2012), the design of the specific pictorial presents some  
22 criticalities in terms of meaningfulness or semantic distance (Chan and Chan, 2013); the  
23 presence of the harrow may focus attention on the direction of the movement of the cylinder  
24 rather than on the need to secure it.

1           The low comprehension rate of pictorial #6 is rather surprising, if we consider the high  
2 comprehension rate of pictorial #3, which also refers to a PTO-related hazard, and the fact  
3 that tractors are the most commonly used agricultural machine (Iftikhar and Pedersen, 2011),  
4 and each tractor is equipped with a PTO. Therefore, users have many occasions to encounter  
5 this pictorial while working, and indeed, over 77% of the participants reported having already  
6 seen it. The present result may be interpreted by considering what is reported by Rogers et al.  
7 (2000), “users might not comprehend the significance of the warning if prior experience with  
8 the product has been benign” (p.122). That is, if farmers usually operate a PTO without being  
9 involved in accidents and injuries, it is possible that they do not pay attention to the pictorial  
10 referring PTO shaft-related risk, do not ask themselves about its meaning and simply ignore it  
11 because they think they know how to operate PTO shafts safely. The same interpretation may  
12 be used for the low comprehension rates of pictorials #5 and #8, warning against electrocution  
13 and incorrect maintenance procedure. However, these results deserve further investigation in  
14 future studies.

15           The low comprehension rates for pictorials #7, #10 and #12 may result from design  
16 deficiencies. Regarding pictorial #7, neither the number of people represented in the pictorial  
17 nor the way they are positioned are clear, raising questions such as, “Is it showing one person  
18 in two positions or two people?”; “What activity is being performed?”; or “What is the person  
19 on the right doing?”. With regard to pictorial #10, its meaningfulness and semantic distance  
20 may be critical, the pictorial intends to inform the user about the need to *read and understand*  
21 the warning notes printed in the user manual, but in the pictorial, these actions are not  
22 represented. Finally, pictorial #12 may lack in concreteness and semantic depiction; based on  
23 what elements should we understand that it represents a wheel?

24           The possible interpretation of the present results raises some considerations about the  
25 need to further investigate the role played by pictorial characteristics in affecting

1 comprehension of safety pictorials affixed to agricultural-machinery, as it has already been  
2 done in other sectors (Chan and Ng, 2010a; Ng and Chan, 2008). Identified critical aspects  
3 may benefit from some re-design interventions (Edworthy et al., 2004), including also the  
4 opportunity to combine the graphical sign with some textual keywords, to improve the  
5 comprehension of complex hazards (Wogalter et al., 2006).

6         With regard to the variables affecting pictorials' comprehension, comprehension  
7 increased with increasing years of experience with agricultural machinery. This result is  
8 consistent with the one reported by Caffaro and Cavallo (2015) from a similar investigation  
9 among Italian users, and it may be interpreted by considering that by developing familiarity  
10 with the machine through routine upkeep and inspection, the operator can increase his/her  
11 knowledge of the potential safety hazards and related pictorials (Rogers et al., 2000).

12         The results about the role played by experience with machinery in enhancing  
13 comprehension may raise some considerations about the need for training interventions to  
14 explain pictorials' relevance and meaning to those who are inexperienced in the use of  
15 agricultural machinery and who thus may be at higher risk. Regarding training methods, Chan  
16 and Ng (2010b) proved the effectiveness of a recall training, in which participants are first  
17 notified about the meaning of the targeted symbols and then have to orally recall the meaning  
18 of randomly selected symbols.

19         This same suggestion may also come when considering the results about the poorer  
20 comprehension performance of part-time farmers occasionally using machinery. These kinds  
21 of operators represent an important part of the U.S. agricultural population. Figures from the  
22 2012 U.S. Agricultural Census depict the dimensions of the part-time farming; the farm is the  
23 place of residence for three fourths of the farmers, but the farm does not provide the majority  
24 of their household income, as 57% of these farms had less than 25% of household income  
25 deriving from their farm; 52% of the farm households had a primary occupation other than

1 farming; and 40% of the principal operators worked off the farm for 200 or more days per  
2 year (USDA, 2014c).

3 Part-time workers are especially employed in agriculture worldwide (Lien et al.,  
4 2006), following the general trend of the last 20 years of significant growth in labour  
5 governed by casual, part-time, subcontract or franchised arrangements, virtually in all OECD  
6 countries and throughout different sectors (Ferrie et al., 1999). The results of international  
7 research show that precarious labour is associated with increased fatalities, occupational  
8 injuries, and illness in various industry sectors across a number of countries (Caffaro et al.,  
9 2017; Fabiano et al., 2008). Fabiano et al. (2008), in their study on temporary work involving  
10 different industrial sectors, interpret this incidence as being due to a lack of experience in the  
11 activity, to insufficient specific knowledge (formal and informal) about the specific machines  
12 and tools to be used, and to inadequate training periods in temporary workers. Possible  
13 methods to be adopted to promote safety may include diffusion of information on regulatory  
14 provisions, management training in safety, enhancement of specific training, and formation  
15 targeted to personnel hired through staffing agencies, as well as implementation of health and  
16 safety regulations for temporary workers. Similar considerations may apply to part-time  
17 workers in agriculture, who may need specific training interventions to increase their  
18 comprehension of safety pictorials when dealing with hazardous machinery.

19 This study presents some limitations that must be taken into account.

20 The survey was carried out in the state of Pennsylvania. Studies regarding a local area  
21 involve participants with a similar cultural background and thus can provide more comparable  
22 data (Smith-Jackson et al., 2010). However, in the future, it would be useful to extend the  
23 study to additional areas of the U.S. to obtain more generalizable results.

24 With regard to the sample, two considerations should be made. The first is in relation  
25 to the very limited participation of women, which did not allow to analyse the gender effect.

1 Since the participation of women in the agricultural sector is increasing (de Schutter, 2013), a  
2 balanced design should be adopted in future similar studies to investigate the issue. The  
3 second deals with the educational level of the participants of the study: over 40% of the  
4 interviewees obtained a university degree. Statistics of the United States Department of  
5 Agriculture report high school graduation to be the highest educational attainment for almost  
6 42% of farm operators, whereas 25% attended some college and 24% completed college  
7 (USDA, 2007, as reported in Hoppe et al., 2010). Thus, our sample seems to be more  
8 educated than the average population of U.S. farm operators. Although previous studies found  
9 no effects of education either on the comprehension rates of safety pictorials (Rubbiani, 2010)  
10 or on the occurrence on injuries (Narasimhan et al., 2010), the role played by education  
11 should be investigated more in detail by considering populations with low or limited literacy  
12 as well.

13 Another limitation of the study arises from the limited number of pictorials  
14 investigated. We considered 12 pictorials, referring to frequent risks involving agricultural  
15 machinery; however, it should be noticed that the ISO 11684:1995 standard provides over one  
16 hundred examples of pictorials describing machinery-related hazards in over 10 categories  
17 (e.g., entanglement hazards, cutting hazards); therefore, other pictorials could be considered  
18 in future investigations to widen the results of the present study. Furthermore, data regarding  
19 previous exposure to the pictorials was solely based on self-reports. The effects of this  
20 variable could be better investigated in future research by means of an experimental design in  
21 which pictorials' comprehension would be tested by exposing different groups of participants  
22 to pictorials for a different length and number of times, to gather information about the  
23 effectiveness of exposure in enhancing pictorials' comprehension.

24 Finally, in a possible development of the research, it may be useful to also assess the  
25 history of previous accidents incurred by the participants (Narashiman et al., 2010) to further

1 investigate the relationship between experience and pictorial comprehension, and how  
2 previous exposure to positive vs. negative outcomes in the use of machinery may enhance or  
3 hinder comprehension of safety pictorials.

#### 4 **5. Conclusions**

5 The results of the present study indicate that only 5 out of 12 investigated pictorials  
6 yielded a comprehension level not significantly different from that of the 85% recommended  
7 in ISO and ANSI standards for a pictorial to be considered acceptable. The 7 pictorials which  
8 were poorly comprehended referred to different hazards, ranging from crushing to  
9 entanglement hazards or hazards related to maintenance activities. This low comprehension  
10 could be interpreted mainly in terms of pictorial design deficiencies. Further investigation is  
11 needed that specifically addresses the design of these pictorials, to identify those aspects  
12 which may benefit from a re-design intervention. With regard to the familiarity with the  
13 investigated pictorials, no clear patterns of relationship between familiarity and  
14 comprehension level were identified for the different pictorials, but overall, two out of five of  
15 the people participating in the survey declared having never seen the pictorials included in the  
16 study, thus not being familiar with them. Increasing familiarity with pictorials by means of  
17 focused training activities or a better placement of the pictorials on the machine and in the  
18 user manual, could make the pictorials more noticeable, memorable and better comprehended.  
19 Similar considerations may be applied to users' variables affecting comprehension, as  
20 previous experience with machinery enhanced pictorial comprehension, whereas being a part-  
21 time farmer using machinery occasionally was related to poorer comprehension performance.  
22 Part-time and unexperienced workers are especially exposed to the risk of accidents in  
23 different sectors and more information is needed about their own specific safety needs.

24 It should be noted that the present study gives only some insights into the  
25 comprehension of a few frequently used safety pictorials, and further research is urgently

1 needed on this topic. The expansion of this research area is also very relevant for agricultural  
2 machinery companies, as a low comprehension of safety pictorials may entail the risk of  
3 limitations of commerce in the multinational markets, given the safety regulations and  
4 standards included in international free trade agreements. Furthermore, more comprehensible  
5 pictorials overcome language barriers and enhance the communication of safety information  
6 to immigrant workers who may not correctly understand the local language.

7

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15

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23

1                      Table 1. Main farming and accidents statistics for the U.S. and Pennsylvania.

	U.S.	Pennsylvania
Overall farm land (ha) <sup>a</sup>	377.5 million	3.124 million
Number of farms <sup>a</sup>	2.08 million	58,800
Average farm size (ha) <sup>a</sup>	177	53
Farm sales >100,000\$ <sup>a</sup>	19.6%	20.7%
Number of all operators <sup>b</sup>	3.2 million	59,237
Gender of principal operator <sup>b</sup>	Male 86.33%	Male 85.73%
Farming primary occupation <sup>b</sup>	1.01 million	30,638
Average age of principal operator <sup>b</sup>	58.3	56.1
Average years on farm <sup>b</sup>	25.0	24.8
Accidents	568 deaths in 2014 <sup>c</sup>	141 fatalities in 2010-2014 <sup>d</sup>
Main cause of accidents	Tractors (36%) <sup>e</sup>	Tractors (44.4%) <sup>f</sup>

2  
3 *Note.* <sup>a</sup> Source: USDA, 2015; <sup>b</sup> Source: USDA, 2014b; <sup>c</sup> Source: NIOSH,2016; <sup>d</sup> Source: Görücü et al.,  
4 2015; <sup>e</sup> Source: USDA 2011; <sup>f</sup> Source: Penn State Extension, 2016  
5

1 Table 2. Characteristics of those involved.

Variables	Levels	<i>n</i>	%	<i>M</i>	<i>SD</i>
Gender	Males	188	90.9		
	Females	19	9.1		
Age				44.2	16.9
Occupation	Farmer	100	48.1		
	Farm worker	38	18.3		
	'Part time' farmer <sup>a</sup>	57	27.4		
	Other <sup>b</sup>	13	6.3		
Education	Middle school	17	8.2		
	High school	94	45.2		
	University degree	97	46.6		
Frequency of machinery use	Regular	253	73.6		
	Occasional	54	26.4		
Years of experience				27.9	17.6
Farm size	Small (up to 19 ha)	27	13.0		
	Middle (from 20 ha to 199 ha)	140	67.3		
	Large (200 ha or larger)	41	19.7		

2  
3 *Note.* <sup>a</sup> 'Part time' farmers: those who do not have an official role in the agricultural industry but, in  
4 addition to their main occupation, spend time working in agriculture and using agricultural  
5 machinery (Singh & Williamson, 1981). <sup>b</sup>Other: includes persons who work with or are around  
6 agricultural machinery as they market them, repair them or offer technical assistance.  
7

1 Table 3. Correct, partially correct, sum of completely and partially correct, and incorrect  
 2 answers for the 12 safety pictorials studied.

Pictorial #	Completely correct <sup>a</sup> (%)	Partially correct (%)	Completely correct/ Partially correct (%)	Incorrect (%)
1	26.9	4.3	31.3	68.7
2	61.5	26.0	87.5 <sup>b</sup>	12.5
3	48.6	32.2	80.8 <sup>b</sup>	19.2
4	70.2	19.7	89.9 <sup>b</sup>	10.1
5	48.6	20.7	69.2	30.8
6	53.4	4.3	57.7	42.3
7	33.2	44.7	77.9	22.1
8	64.9	5.8	70.7	29.3
9	78.4	11.5	89.9 <sup>b</sup>	10.1
10	45.2	18.3	63.5	36.5
11	44.7	39.4	84.1 <sup>b</sup>	15.9
12	42.8	15.4	58.2	41.8
Mean(SD)	51.53(15.00)	20.19(13.36)	61.21(15.02)	28.28(17.25)

3 *Notes.* <sup>a</sup>All percentages of completely correct answers are significantly less than 85% in non-  
 4 parametric Chi-square tests. <sup>b</sup>Percentages are not significantly less than 85% in non-parametric  
 5 Chi-square tests.

6

7

1 Table 4. Familiarity with the 12 pictorials studied.

Pictorial #	“Have you already seen this symbol?”(%)		
	Never	Sometimes	Often
1	39.4	44.2	16.3
2	32.2	42.3	26.0
3	51.9	38.0	10.1
4	42.3	46.2	11.5
5	39.4	48.6	12.0
6	21.6	43.3	34.1
7	58.7	35.1	6.3
8	53.8	38.5	7.7
9	45.7	41.8	12.5
10	36.1	49.0	14.9
11	24.0	56.3	19.7
12	47.1	43.8	8.7
Mean(SD)	41.02(11.40)	43.93(5.69)	18.98(8.14)

2

3

1 Appendix A.

2

3 Below you will find 12 safety pictorials that are usually found on different types of  
4 agricultural machinery.

5 For each pictorial, please choose the most suitable answer from the four alternatives. **You**  
6 **can only choose one answer.**

7 Even if you are not familiar with all of the pictorials it is important you answer as we are  
8 interested only in your interpretation of them.

9

10 **THANK YOU FOR YOUR COOPERATION!**

11

	<p>What do you think this pictorial means?<sup>a</sup></p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Secure lifting cylinder with locking device before accessing hazardous area</li> <li><input type="checkbox"/> Insert locking device to prevent the lifting cylinder from falling</li> <li><input type="checkbox"/> Use lift arm supports during maintenance that requires lift arms to be raised</li> <li><input type="checkbox"/> Insert locking device on lifting cylinder by operating in the direction shown</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Consult Operator's Manual for proper service procedures</li> <li><input type="checkbox"/> Follow the maintenance procedures shown in the Operator's Manual</li> <li><input type="checkbox"/> Store Operator's Manual in a safe place</li> <li><input type="checkbox"/> Operator's manual is placed in the toolbox</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Check the direction of rotation and revolutions of the Power Take-Off before assembling the drive shaft</li> <li><input type="checkbox"/> Check the revolutions of the Power Take-Off before assembling the drive shaft</li> <li><input type="checkbox"/> Check the angle of rotation of the Power Take-Off before assembling the drive shaft</li> <li><input type="checkbox"/> Check that the Power Take-Off is working before assembling the drive shaft</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Do not place your feet under rotating knives</li> <li><input type="checkbox"/> Do not place your lower limbs close to moving units</li> <li><input type="checkbox"/> Keep your feet away from falling weights</li> <li><input type="checkbox"/> Do not rotate drive units by foot</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>

<p>5</p> 	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Do not maneuver loader near electrical wires</li> <li><input type="checkbox"/> Loader bucket can become caught on electrical wires</li> <li><input type="checkbox"/> All electrical wires near the machine are energized</li> <li><input type="checkbox"/> Do not touch the metal parts of the machine because they are energized</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
<p>5</p> 	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Do not work on input drivelines while engine is running</li> <li><input type="checkbox"/> Do not get close to the moving units while engine is running</li> <li><input type="checkbox"/> If you get caught do not touch the rotating driveline with your hands</li> <li><input type="checkbox"/> Ensure the driveline is securely attached at both ends</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
<p>7</p> 	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Stay clear of the draft link lifting range while operating rockshaft controls</li> <li><input type="checkbox"/> Never stand behind the tractor while engine is running</li> <li><input type="checkbox"/> Do not stand behind the tractor to hitch/unhitch equipment</li> <li><input type="checkbox"/> Do not activate the lift if other persons are around</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
<p>8</p> 	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Shut off engine and remove key before performing maintenance or repair work</li> <li><input type="checkbox"/> Disengage the power and stop the machine before servicing</li> <li><input type="checkbox"/> Read all instructions in the Operator's manual before starting the machine</li> <li><input type="checkbox"/> Shut off engine and remove key while waiting for technical assistance</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
<p>9</p> 	<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Always lock ROPS in upright position</li> <li><input type="checkbox"/> Lock ROPS in upright position when riding on slopes</li> <li><input type="checkbox"/> Foldable ROPS can accidentally deploy</li> <li><input type="checkbox"/> Raise the ROPS operating in the shown direction</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>

0		<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Read Operator's Manual</li> <li><input type="checkbox"/> Operation manual must be with the machine at all times</li> <li><input type="checkbox"/> Consult machine spare parts catalogue</li> <li><input type="checkbox"/> Store the Operator's manual</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
1		<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Do not drive where the vehicle may lose grip or balance</li> <li><input type="checkbox"/> Do not travel in a cross direction on a slope as it may cause the vehicle to roll over</li> <li><input type="checkbox"/> Should the vehicle roll over, do not jump out of the cab</li> <li><input type="checkbox"/> Do not turn uphill when operating on slopes</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>
2		<p>What do you think this pictorial means?</p> <p>ATTENTION:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Chock wheels to ensure the machine is secure</li> <li><input type="checkbox"/> Wedge chock blocks securely</li> <li><input type="checkbox"/> Ensure that vehicle park brake is engaged</li> <li><input type="checkbox"/> Chock wheels securely if jacking-up</li> </ul> <p>Have you ever seen this pictorial?</p> <p><input type="checkbox"/> never      <input type="checkbox"/> sometimes      <input type="checkbox"/> often</p>

1  
2  
3  
4  
5

Note. <sup>a</sup> For the reader's convenience, the labels are reported in the following order per pictorial: the first answer is the correct answer, then the partially correct and the two incorrect labels follow.