Comprehension of Safety Pictograms Affixed to Agricultural Machinery among Pakistani Migrant Farmworkers in Italy

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Abstract

Objectives: Safety pictograms are important graphic elements that are useful for rapidly conveying messages in workplaces. The purpose of this study was to investigate the comprehension of safety pictograms affixed to agricultural machinery among a group of Pakistani migrant farmworkers employed in Italy.

Methods: Twenty-nine Pakistani migrant farmworkers employed on Italian farms were interviewed on the meanings attributed to 4 standardized safety pictograms affixed to agricultural machinery depicting the most frequent causes of farm accidents were assessed.

Results: The results showed high variability in pictogram comprehension. None of the participants interpreted all the pictograms in accordance with the definitions provided by the international standards. Higher comprehension rates were reported for pictograms related to the risks of tractor rollover and foot injury, while pictograms referring to the need to consult a technical manual and the risk of entanglement yielded lower comprehension scores. Previous farming experience in the country of origin and the number of years of education were significantly associated with comprehension scores.

Conclusion: A discussion of pictogram features that may be critical for comprehension is provided, and (re)design suggestions are given to improve the cross-cultural comprehension of these safety signs.

Keywords: Migrant farmworker; Occupational safety; Pictogram comprehension.

Introduction

Pictograms, or pictorial representations, briefly synthesize complex messages, explain simple actions and capture and keep people's attention. They are often used to represent hazards or their consequences to help people to rapidly understand several kinds of safety messages. They are considered a universal form of communication since they have the advantage of being better understood than written messages.[1] To support the universal comprehension of safety pictograms, for the past 30 years, the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI) have developed different standards to provide a "uniform graphic system for communicating safety and accident prevention information"[2](p. V). These standards[2–5] provide "guidelines for good graphical design of hazard pictorials as well as instructions for drawing the human figure and other pictorial elements" (e.g., machinery and arrows)[6](p. 11).

Pictogram comprehension has been investigated in several fields in relation to traffic signs,[7] medical and pharmaceutical products,[8] mining,[9] construction,[10] the industrial sector,[11] and chemicals labels.[12] Despite the expected ability of pictograms to be easily comprehended by all users, many studies have shown that some signs are easier to understand from the first exposure, while others are particularly difficult to comprehend,[13] and that some characteristics of the target audience can influence the interpretation of symbols.[14] The nationality of the user has been shown to significantly affect the comprehension of pictograms,[15] whereas contrasting results have been reported regarding age, education and previous experience. Some studies demonstrated better comprehension among younger[16] and more highly educated people,[17] who had higher familiarity with the targeted pictograms,[18] whereas others reported no effect of these variables.[19] The characteristics of the target audience can also contribute to explain the inconsistent results reported in the literature on the association between pictograms knowledge and behavioral compliance. Indeed, as discussed by Laughery and Wogalter[20] the fact that people using hazardous products or

performing some task in a hazardous environment decide to comply with a warning sign depends on both the design of the sign (including features as complexity, meaningfulness and semantic closeness)[18] and the characteristics of the persons involved.

The comprehensibility of safety pictograms is particularly relevant in those workplaces where growing international trade and globalization increase the cultural diversity of the workforce, which often results in migrants working under the management of foreign leadership.[21] This scenario is common in the agricultural sector, which has a high employment rate of migrant workers.[22] Agriculture is also one of the productive sectors with the highest risks of accidents and injuries since workers are typically exposed to potentially dangerous vehicles, machinery, substances and environmental conditions.[23] Concerning migrant farmworkers,[24] the diversity of languages, reading skills, experiences, cultures and countries of origin often increases the level of risk by preventing workers from understanding safety information.

Although agricultural machinery has benefited from substantial progress in safety and ergonomics since the 1980s,[25] interaction with machinery is still the main cause of accidents.[26,27] This is especially because of tractor rollover, machinery maintenance and sharpening/rotating parts of machinery that could pinch, cut or catch different parts of a worker's body.[28,29] To reduce potentially risky situations, machinery design need to follow a safety hierarchy protocol that consists of different phases: (a) physically remove or eliminate the hazard based on the design of the machine itself, (b) isolate people from any hazards that could not be eliminated through the machinery design with appropriate engineering devices, (c) protect users with personal protective equipment (PPE), (d) train users about the hazards and how to avoid personal injuries, and (e) warn users about the potential residual hazards/risks.[30] Pictograms refer to point (e) of this safety hierarchy protocol since they have the purpose of informing about the presence of danger and how to avoid it, pushing users to action and changing their attitudes.[1] Several standards[6,31] have been developed to define the characteristics of pictograms that are affixed to agricultural machinery. Safety pictograms are required to be affixed to tractors and agricultural machinery in European

Union countries and are regulated by law,[32] whereas they are voluntarily adopted in the United States.[2]

Although pictograms are important for communicating safety information and machines are the main cause of fatal and nonfatal accidents in agriculture, safety pictograms have been investigated mainly with regard to pesticide labels and less with regard to agricultural machinery. Concerning pesticides, previous studies conducted among local, as opposed to migrant, farming populations[33] reported that farmworkers had a low level of comprehension and awareness of the information conveyed by safety labels. Moreover, in a review study conducted by Emery et al.,[12] 11 relevant articles were identified that were specifically related to the use of pictograms for communicating hazard and safety information in relation to the use of pesticides. Among these 11 studies, only one[34] focused on migrant farmworkers (Latino farmworkers), and it reported frequent confusion over the symbols adopted to convey safety and health information on pesticides.

With regard to pictograms affixed to agricultural machinery, to our knowledge, only five studies[35–37] have investigated this issue. Two of these studies involved observational inspections of the presence of safety signs on machinery and their visibility status,[38] while the other three studies assessed pictogram comprehension among Italian and Pennsylvanian farming populations, showing different levels of comprehension.[35–37] However, these studies referred to local populations, while to our knowledge, there is no study specifically investigating the comprehension of safety pictograms affixed to agricultural machinery among migrant farmworkers.

Context and purpose of the present study

Agriculture is one of Italy's key economic sectors. Approximately 500,000 of 1,432,925 workers employed in the sector are migrant workers; among these, more than 224,000 are from non-EU countries,[39] and an increasing number are coming from Pakistan. In 2016, statistics showed that the number of employment contracts signed by Pakistani migrants was 40,229. Agriculture represented the second largest sector in terms of the number of migrants recruited, reporting 30.4%

of new contracts with Pakistani migrant workers, which was a higher rate than that of contracts registered with other non-EU citizens.[40]

Migrant workers in Italian agriculture are often employed with fixed-term contracts during specific periods of the year for fruit and vegetable harvesting, whereas for livestock and poultry production, migrant workers hold stable full-time employment at a farm and also often use agricultural machinery.[23] Migrant farmworkers are involved in accidents and physical injuries more than local workers. In 2013, the rate of nonfatal injuries was 3.3% among migrants compared to 2.8% among Italian workers.[41] Regarding the total number of nonfatal injuries from 2013 to 2017, a decreasing rate was reported for Italian farmworkers, from nearly 35,000 to 29,000, while an increasing rate was reported for non-EU migrant farmworkers going from nearly 3,400 to 3,550.[42] According to the national statistics,[43] in 2015, 193 out of 1,246 fatal accidents in agriculture involved migrant farmworkers, with an increase of 9.5% for workers from other EU countries and of 26.5% for non-EU workers.

Based on the previous considerations, in the present study we were interested in exploring whether four safety pictograms affixed to agricultural machinery were comprehensible for Pakistani migrant farmworkers employed in Italy, analyzing the meanings attributed by the participants to the investigated pictograms and their correctness compared to the intended meanings provided in the international standards.[6] In addition, we intended to investigate whether pictograms comprehension was affected by the sociodemographic characteristics of the participants, considering the effects of age, education, length of stay in Italy, and previous experience in farming on pictograms' comprehension. The selected pictograms referred to the most common accidents involving machinery in Italian agriculture. The present investigation intended therefore to provide a useful contribution to the topic of safety communication among the migrant workforce in highly hazardous sectors, revealing critical issues in safety pictogram comprehension, which may benefit from targeted training interventions and/or (re)design suggestions, to enhance comprehensibility and therefore promote occupational safety and health.

Materials and methods

Participants

A group of Pakistani migrants working on livestock farms in the province of Cuneo, Piedmont Region, northwestern Italy, were involved in this study. The Piedmont Region could be considered a good representative of Italian agriculture given the characteristics of its agricultural system and high rate of employment of non-EU migrant farmworkers.[44] In addition, previous research has shown that farmers from Piedmont can be effectively surveyed to analyze the dynamics of the Italian farming population.[35,36,45] The province of Cuneo in particular is characterized by the most extensive Utilized Agricultural Area (UAA, namely the total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens used by the agricultural holding, regardless of the type of tenure)[46] and the largest number of agricultural operations of the region, as well as by the higher percentages of both the family labor force and external labor force based on migrant workers.[47]

Instrument

Four pictograms affixed to agricultural machinery according to the International ISO 11684:1995[6] standard were selected for the study. They were selected from the set of twelve pictograms whose comprehensibility has already been investigated among local farming populations in both Italy[35,36] and the Pennsylvania (US).[37] The pictograms were chosen based on previous evidence regarding the most frequent machinery-related accidents[26] and the Italian statistics about the main causes of fatal and nonfatal accidents in interactions with agricultural machinery in the years 2012-2015 (i.e. 372 accidents related to tractor rollover, 183 caused by unintentional movements of the machine during maintenance, and 83 related to cuts from and entanglement in moving parts of the machinery).[48] Thus, the four pictograms selected for the study warned against accidents during machinery maintenance, entanglement caused by the power take-off, cut of foot from machinery and tractor rollover (Table 1). The pictograms were for the purpose of hazard avoidance, i.e., they presented visual instructions on how a person should behave to avoid

hazards in the interaction with machinery and equipment.[6] Concerning the layout of the pictograms, the format with two illustrative, vertical panels was selected, with a safety alert symbol above and the hazard avoidance pictogram below. This choice was made considering that the study ~~was~~ intended to investigate the comprehension of graphical symbols only, as in the research study of Caffaro, Mirisola, and Cavallo.[36]

Pictograms were presented on four printed sheets showing one safety pictogram each. The pictograms were presented in the same color and size recommended by the ISO standard 11684:1995[6] and ANSI Z535.3-2017[2]: black drawings on a yellow background, 88x168 mm each. Following the ANSI Z535.3 2017[2] guidelines, safety sign comprehension was assessed using open-ended questions in which participants were asked to describe the meaning of each symbol in their own words.[49] Pictograms were shown in randomized order. A standard sociodemographic form followed.

Procedure

A list of farms employing Pakistani migrants in the area selected for the study was provided by the local branch of a national farmers' organization. Farmers were contacted by telephone, and if they agreed to let their workers participate in the study, we scheduled an appointment in their farms to meet their Pakistani farmworkers. During the on-farm meeting, the Pakistani workers were asked if they were willing to participate in the study. Participants who agreed were interviewed by the authors in a dedicated room without the employer to avoid any conditioning. Although the participants in the study had passed the compulsory test of basic knowledge of the Italian language, following the same procedure adopted by Smith-Jackson and Johnson,[50] an interpreter supported migrants to understand the questions in case any difficulty.[50] The instructions ("You will see four safety pictograms usually found on different types of agricultural machinery. For each pictogram, please tell us what it means to you.") were orally administered in Italian and, when necessary, translated by the interpreter. Similarly, when participants were not familiar with Italian, they responded in their mother tongue, and then the interpreter translated the information back to the

interviewer. The interpreter had been previously trained about safety risks in the agricultural sector and about the meanings of the safety pictograms that would be shown to the participants during the interview. Based on the method adopted in other studies,[50] each participant was individually interviewed, and the responses were audio-recorded. After each participant gave his interpretation of each of the four safety pictograms, the correct meaning was explained. The entire interview lasted between 20 and 40 minutes for each participant.

Participation in this study was voluntary, and no incentives were given. All participants were informed about the nature of the study and signed an informed consent form. The study was approved by the Research Advisory Group (RAG) of the Institute for Agricultural and Earthmoving Machines (IMAMOTER) of the National Research Council of Italy (CNR).

Scoring and data analysis

The data collected by means of the open-ended questions underwent an initial qualitative data analysis, which allowed us to explore the varied and multiple subjective meanings of farmworkers' experiences, offering "relevant insights for both envisioning design opportunities and formulating design requirements" [51 (p. 68)]. Then, as done also in previous studies, [10,52,53] the qualitative themes were transformed into counts and these counts were used for subsequent quantitative statistical analysis, to investigate the role played by different individual variables in affecting pictograms' comprehension.

In the first qualitative step of our analysis, the interviews were transcribed verbatim and then subjected to a content analysis supported by NVivo software v.11. As stated by ANSI Z535.3:2011 standard, the primary criterion for determining symbol effectiveness is that of comprehensibility; that is, "that the symbol clearly conveys the intended message to the appropriate target population. Criteria of 85 percent correct responses […] is suggested for acceptance of a given symbol."[2](p.25). Therefore, participants' responses were grouped into correct and incorrect answers, based on the intended meaning provided in the ISO standard 11684:1995[6] for each pictogram (Table 1). Correct answers included responses that captured variations of the intended meaning when symbols were

defined not only in concrete terms (i.e., the people, the objects or the part of the machinery represented) but also conceptually, identifying the potential hazard in the human-machine interaction and the action to avoid it; incorrect answers included incorrect answers, nonresponses, or answers that demonstrated critical confusions (i.e., “When a safety symbol elicits the opposite, or prohibited action. For instance, when a safety symbol meaning "No Fires Allowed" is misunderstood to mean "Fires Allowed Here"”, ANSI Z535.3:2017, p. 1).[2] To determine the correctness of the respondents’ interpretation (i.e. the correct comprehension of the targeted pictogram), two independent judges coded the responses, reaching an initial agreement rate of 84%; any disagreement was discussed until consensus was achieved. Each participants’ response was then scored as 1 if it reported a correct comprehension of the pictogram’s meaning, whereas it was scored as 0 if the interpretation of the meaning of the pictogram was incorrect, based on ANSI Z535-3:2017.[2] All the chunks of text coded as 1 (i.e. answers indicating correct comprehension) were then sorted into sub-categories based on the similarities or differences of their content until saturation was reached, which occurred when no new coding sub-categories about the topics under investigation emerged from the interviews.[54] The same was done for incorrect responses. The frequency of occurrence of correct and incorrect answers and their sub-categories for the four pictograms was then calculated.

To quantitatively investigate any possible effects of individual variables on pictogram comprehension, a total comprehension score for the four investigated pictograms was computed for each participant as a sum of the correct responses, each scored as 1 as described in the previous paragraph. Therefore, the total comprehension score per participant ranged from 0 (no correct responses at all, for any of the pictograms considered) to 4 (four correct responses, one for each pictogram considered). A one-way Analysis of Covariance (ANCOVA) was then performed on this total score, with previous experience in agriculture in the country of origin (1= previous experience in farming, 0 = no previous experience in farming) as the between-subjects factor and age, education, and number of months living in Italy as covariates. Prior to analysis, diagnostic and

normality tests were conducted. Scatter plots and histograms were generated and Shapiro-Wilk tests performed for the variables considered in the analysis (i.e. age, education, number of months living in Italy and the total comprehension score). Number of months in Italy and the total comprehension score showed a positive skew. Transformations were unsuccessful in achieving normality for these variables. However, adopting the same approach reported by Govindu and Babski-Reeves (2014)[55] and Caffaro et al.[56] and since the analyses used for the study are known to be robust with regard to normality assumptions,[57] the data were used in their raw format. In the Results section, the frequencies of correct and incorrect answers are reported for each pictogram, and some quotations from the interviews are reported to better illustrate the aspects highlighted as critical for pictogram comprehension by the participants and to provide possible suggestions for pictogram improvement. The results from the multivariate analysis follow.

[Table 1 near here]

Results

Twenty-nine male Pakistani farmworkers were involved in the study, with a mean age of 32.3 years (SD=7.5) and a mean length of stay in Italy of 12.6 months (SD=4.0). Mean years of education were 8.0 (SD=2.7), and 11 participants have had some previous experience in farming in their country of origin. -The participants' mother tongue was the Punjabi language, one of the most common native languages spoken in Pakistan. All the participants had already passed the mandatory test of knowledge and comprehension of the Italian language requested by the Italian Occupational Safety and Health (OSH) regulation (Decreto Legislativo 81/08)[58] in the application of the European Framework Directive on Health and Safety at Work.[59] Moreover, the participants had already attended the mandatory health and safety basic training required by the OSH rules to be employed in Italy. The OSH course includes the explanation of the meanings of the most common safety pictograms.

Regarding the investigated pictograms, all the participants recognized the pictogram with the exclamation mark as a symbol of warning and the presence of some form of danger. Their

recognition was evident because in many cases, before explaining the pictogram interpretation, participants used the word "Attention". Concerning the comprehension of the lower panel of the safety signs, the number of participants' correct responses ranged between 3 and 0; no participants gave a correct answer for all 4 pictograms investigated. More specifically, 1 participant (3.4%) provided three correct answers, 8 participants (27.6%) reported two correct answers, and 10 participants (34.5%) gave only one correct answer. The pictogram that yielded the highest comprehension was the one representing the risk of tractor rollover (#4) (with 44.8% reporting correct answers), followed by Pictograms #3, #1 and #2 referring to the risk of cut to the foot, to machinery maintenance-related risks and the risk of entanglement, respectively. Responses given by the participants will be presented separately for each investigated pictogram.

Pictogram #1, related to the need to consult the technical manual to avoid the risk of accidents during machinery maintenance, was correctly interpreted by only 4 out of 29 participants; these 4 participants recognized the representation of a manual that needed to be read prior to repairing machinery, consistent with the definition provided by the International Standard[6] (Table 1): "You have to pay attention! You need to read this book to protect yourself when working on machinery", "A book from which you can learn how to protect yourself when using the machine". Regarding the incorrect answers, 14 farmworkers recognized the machinery component, describing the wrench as the necessary tool to operate on machinery when it does not work (5 participants) or the need to call for technical assistance (3 participants) and to look for the toolbox to repair machinery (6 participants) without citing a specific safety reason. Some statements reported by the participants included the following: "For me, this pictogram tells me I have to call the mechanic, because the machinery has some problems, and it doesn't work" and "There is a hardware store near to repair the machinery".

The answers reported by the other 9 participants were scored as incorrect because even if they recognized the representation of the book, they did not accurately interpret the reasons why the book should be read: "You need this book to operate on the machinery" and "This book is used to

write information about what is OK for the machinery and what is not". Based on this, the concrete objects depicted, i.e., the book and the wrench, were recognized, but it was misunderstood that their functions prevented the farmworker from encountering the hazard. Two participants simply answered, "I have no idea what its meaning is" and "I do not know". At the end, when the pictogram meaning was explained to participants, one of them expressed his opinion: "I think it is not a warning signal because a book and a wrench do not represent danger. I do not understand how I can be injured if I read this technical manual".

Pictogram #2 was related to the risk of whole body entanglement caused by the power take-off drive shaft, warning the farmworker not to work when the engine is running. None of the participants interpreted the pictogram correctly. It is important to note that the incorrect answers given by the participants referred to concepts that were very different from each other. In this pictogram, the entanglement, the power take-off and the entangled person (the whole body) are represented. In their responses, 16 participants interpreted the pictogram as being related to the risk of falling to a lower level or a falling object: "You have to pay attention when you climb on something because you can fall down"; "An object fell on the farmworker's body and hurt him"; and "The person fell down and then was entangled in something".

Three participants recognized machinery as the source of injury but they did not identify the hazard related to the power take-off drive shaft: "The person was injured by the tractor" and "The farmworker has been crushed by machinery". Among the other answers, 4 participants referred to the electrical risk: "For me, this pictogram represents an electrocuted person. The open hand and the representation of the fingers makes me think a man was killed due to electric shock." Similarly, another respondent said, "Maybe this is an electrical tower (indicating the drive shaft), and it is dangerous to climb on it". Four other participants did not have any idea about the possible meaning of the pictogram.

For Pictogram #3, representing the risk of cuts to the foot from machinery with rotating blades, 12 participants gave a correct answer: "Tractor with rotating tools (harrow): be careful not

to cut your feet" and "There is a danger to the feet caused by moving parts on the machinery and a risk of cutting the foot". The answers were reported as correct because responses were close to the definition provided by the standards (Table 1). In addition, those participants recognized the components of the risk of foot injury, the rotating parts of the machinery and the person's foot.

Seventeen participants gave incorrect answers. Among these, 6 participants focused their attention especially on the foot and the need to protect it without identifying the specific hazard depicted (the rotating blade): *"*I need to protect my feet when I'm working near the machinery" and "I have to wear my work shoes to protect my feet". Moreover, 4 participants misinterpreted what could cause foot injury: "You have to pay attention to your feet because you could fall"; "Look out for your foot, because something could crush it"; and "Look out for your foot, because you can slip". Three answers showed the respondent had completely misinterpreted the elements depicted: "I have to pay attention when I used a ladder because I can fall"; "Need to use a safety bar when the plough is running"; and "Do not run over obstacles with the mower". Finally, 4 participants did not report any specific answer concerning this pictogram ("I do not know" and "I do not understand this pictogram").

For Pictogram #4, representing the risk of tractor rollover on sloping terrain, 13 out 29 participants gave the correct answer, primarily because they recognized the risk of driving on sloping terrain and the importance of driving in safe conditions to avoid being crushed in case of tractor rollover: "Be careful when driving the tractor on sloping terrain"; and "Driving on a sloping road is dangerous because you can overturn, and you can be crushed". All the answers reported showed that the tractor rollover, the sloping terrain and the worker were more or less recognized. On the other hand, 16 participants reported incorrect answers. In detail, these farmworkers focused on only one element at a time, namely, the falling person, the sloping tractor or the dangerous road. The different answers had a similar distribution among the 16 participants: "The person is falling from the tractor and the tractor fell down on the person"; "The person is being crushed by the

tractor"; "It is important to use a seatbelt" and "Attention, because the road is dangerous, you have to reduce the driving speed".

With regard to the effects of the sociodemographic variables on pictogram comprehension, the ANCOVA showed a significant main effect of previous farming experience in the country of origin ($F(1,19)=4.43$, $p=.049$), with those employed in agriculture before coming to Italy reporting a significantly higher comprehension compared to those who were not previously employed in agriculture (1.47 vs .76). The analysis also noted a significant effect of the number of years of education ($F(1,19)=6.05$, $p=.024$), which was negatively associated with comprehension ($B=-.152$, $p=.024$), showing that more educated participants reported a lower level of comprehension. Number of months living in Italy reported no significant effects ($F(1,19)=1.56$, $p.=.226$).

Discussion

The results of the current study showed that the Pakistani migrant farmworkers involved in the investigation did not have a complete and exhaustive knowledge of the investigated safety pictograms. Although our participants had already attended a training course in which the meaning of safety pictograms was explained, various incorrect answers were recorded, prompting consideration of the efficacy of training, and making room for alternative training techniques.[60] Taking into account the differences in the adopted method (open-ended questions vs multiple choice answers), it is interesting that, when the comprehensibility of the 4 pictograms was investigated among local agricultural populations in Italy[35,36] and Pennsylvania,[37] quite different response patterns emerged. In these previous studies, the pictograms yielded a comprehension rate ranging from 84.1% to 94.2% and 57.7% to 89.9% for Italian and Pennsylvanian participants, respectively.[35–37] Our Pakistani participants reported instead a comprehension rate between 0% and 44.8%, well below the 85% of correct responses recommended by the ANSI standard[2] for a symbol to be considered comprehensible, highlighting some considerations about the expected cross-cultural comprehension of safety pictograms. Some similarities emerged among the three studies with regard to the most comprehended pictograms. The pictograms related to the risk of cutting the

foot from machinery and to tractor rollover on sloping terrain reported higher comprehension scores among Pennsylvanian (89.9% and 84.1%, respectively) and Italian farmworkers (92.7% and 93.9%), as well as for Pakistani farmworkers (41.4% and 44.8%). In contrast, the pictogram representing the need to consult the technical manual to avoid the risk of accidents during machinery maintenance, generated a high level of comprehension among local workers, with 87.4% of Pennsylvanian farmworkers and 94.2% of Italian farmworkers providing correct answers, while only 13.8% of Pakistani farmworkers reported correct answers. Some differences were reported also for the pictogram related to whole body entanglement. The Italian farmworkers reported a high mean rate of correct answers (84.1%) for this pictogram, whereas Pennsylvanian participants reported a lower correct response rate of 57.7%. Despite the differences in their correct response rates, these previous studies[35–37] showed a better comprehension of the pictogram related to the entanglement of the whole body in machinery compared to the results reported by Pakistani farmworkers, for which the pictogram was particularly difficult to understand (100% of the respondents reported incorrect answers). The high level of comprehension among American and Italian farmworkers could be interpreted in terms of a higher familiarity of these farmworkers with either the pictogram or the issue of entanglement due to several safety campaigns in both countries that insisted on working carefully when close to the power take-off drive shaft.[61]

Regarding the comprehension score yielded by each pictogram that was investigated, higher comprehension rates were reported for the pictogram related to tractor rollover on sloping terrain (#4) and to the risk of cutting the foot from machinery (#3), while lower comprehension rates were reported for pictogram #1, referring to the need to consult the technical manual to avoid machinery maintenance-related risks, and #2, referring to the risk of whole body entanglement. Pictogram #4, concerning the risk of tractor rollover, was the most comprehended pictogram. Considering that tractor rollover is one of the main causes of fatal injuries in the agricultural sector,[62] the high score reported for this pictogram is encouraging because its correct interpretation can positively influence farmworkers' behavior. Consistent with previous research,[18] in which pictograms characterized by

high concreteness and semantic closeness were better comprehended, the high comprehension may be due to some pictogram's good design features, since the pictogram clearly shows concrete dramatic action in which the worker and the cause of the accident are depicted. According to the participants' answers, both the machinery and the specific hazard related to the interaction with the machinery were well recognized, even though the role of the slope was not recognized and the correct hazard avoidance behavior was not always identified: some participants described the road differently, highlighting curves and the need to reduce the driving speed or to use a seatbelt, which indicates that the representation of the steepness of the slope could be improved. As suggested by the ISO,[6] an arrow indicating a downward trajectory could be useful.

Concerning the pictogram representing the cutting of the foot from machinery (#3), the high level of comprehension achieved could be considered a positive factor, given that many agricultural machines are equipped with rotating knives or blades. In particular, participants focused on the description of the person: most of the participants recognized the representation of a foot and the need to protect it, suggesting a good level of concreteness[51] of the representation. Interestingly, some participants' answers mentioned wearing safety shoes, suggesting the need to improve the foot representation, since in its present form it may not feature a safety boot but rather a 'common' shoe. This redesign could be useful to focus users' attention on the actual hazard posed by the interaction with the machinery rather than on the kind of shoe depicted. Although the foot injury hazard was reported by a large portion of migrants, the rotating movement of the blades was less comprehended, despite the arrow suggesting the rotating movement. However, there might have been some issues related to the hierarchy of information conveyed, since the foot and the blades are both depicted using a solid (filled) graphic form. Furthermore, to enhance pictogram comprehensibility, it may be useful to highlight the actual consequence in case of an accident or focus on the tool that could cause the accident.

The pictogram referring to the consultation of the technical manual as a proper service procedure to avoid the risk of accidents during machinery maintenance (#1) yielded a poor

comprehension score. Its low level of comprehension is consistent with the evidence that the maintenance of mechanical components of the machinery and the lack of manual reading are two dangerous and linked factors since nearly 18% of injuries take place while farmworkers are performing maintenance work.[29] The participants' responses showed that the two depicted elements (the book and the wrench) were perceived as two separate objects, not understanding the correct relationship between them and what the farmworkers must do to comply with the pictogram. In addition, the last comment given by one participant suggested that the two objects depicted did not communicate a dangerous situation. The participant's comment pointed out this critical issue, highlighting the difficulty of representing a large amount of information in a single pictogram. Furthermore, participants' responses showed that they were more focused on mechanics and maintenance than on safety and the need to protect themselves. These findings suggest that the meaningfulness of the pictogram may need to be enhanced,[42] possibly improving the representation of the action that needs to be carried out, e.g., depicting a farmworker who is reading the book while holding a wrench in the other hand.

Pictogram #2, warning users about the risk of entanglement caused by the power take-off drive shaft, reported the worst results because no participants gave the correct answer. This result is consistent with the high number of power take-off-related injuries occurring every year among farmworkers.[26,48] Considering the elements depicted in this pictogram, the main causes of its misinterpretation could be related to the complex representation[18] of the human body, the power take-off drive shaft and their relationship. Indeed, responses showed that participants focused their attention mainly on the injured person, rather than on the machinery-related hazard or on the possible avoidance behavior: the majority of participants associated the representation of the person in a horizontal position with a person who had fallen down (from a beam, a tree, or an electric tower or while climbing). In addition, a person represented with lifted arms and hands may be the main cause of misunderstanding of the pictogram meaning since it does not allow a focus on the whole body becoming entangled due to the rotation of the machinery component. Based on the responses

some features should be considered to improve the pictogram. The person could be represented in an upright position and bent down toward the power take-off, with one limb or only some parts of the body entangled. Adding an arrow to describe the rotating movement of the machinery component could be another way to avoid misunderstanding related to the entangled person. Some specific references to the tractor (e.g., a wheel, the representation of the rear of the tractor) could also be added to help the participants recognize the danger linked to the agricultural machinery.

In terms of the user characteristics that may influence pictogram comprehension, the analysis in the present study showed that having been employed in farming in the country of origin was associated with higher comprehension scores, whereas more years of education resulted in poorer comprehension. Although these results cannot be considered conclusive due to the small sample size involved in the present investigation, the effect of previous experience in farming is consistent with previous studies[35,45] reporting a positive effect of this variable on pictogram comprehension, and it prompts consideration of the comprehensibility of pictograms for naive users. Contrary to the previous literature, the number of years of education showed a negative association with comprehension, which might be because the more educated participants were also those with fewer years of previous experience in farming. A future development of the research could further investigate this issue by examining the role played by the number of years of previous experience in farming in larger samples of participants.

Overall, considering the present results, some recommendations already applied for other safety signs[6] could be adopted as useful suggestions to redesign the investigated safety signs and make them more comprehensible. First, improving the balance of the solid shapes and outline shapes (ISO 11684:1995)[6] to allow a better distinction between the causes of the accident and the human figure getting injured (Fig. 1a). Second, reducing the number of additional descriptive elements that could crowd the pictogram space causing overload and misunderstanding (Fig. 1b). Third, focusing on the consequences instead of the hazard, for instance, representing a foot being cut rather than a hazardous blade (Fig. 1c). Forth, depicting the targeted action, representing the

worker with a specific object for the task required, instead of depicting the isolated object (the manual book) to increase the concreteness of the messages (Fig. 1d).

[Fig. 1 near here]

Although the present study involved a small group of migrant farmworkers, it revealed some critical issues in pictogram comprehension, which are consistent with previous studies in other fields showing that human perception of safety signs is influenced by cultural background.[50] For these reasons, it appears fundamental to test pictogram interpretation among different cultures and to adopt technical design solutions to enhance pictogram comprehension. A participatory design approach would be an effective tool to promote safety communication that can be easily understood among different categories of users and cultures.[63] An analysis of the needs of users should be performed by directly involving users in pictogram development, and the design arrangements need to be discussed to create a visual hierarchy (i.e. a visual contrast between forms to influence the order in which the human eyes perceive the depicted objects)[64], to improve pictogram comprehensibility.

Limitations of the study and future research developments

The investigation involved a group of migrants from Pakistan. This choice allowed us to have participants with the same cultural background and more comparable data[50]; however, in future research, it will be useful to investigate these issues with migrant farmworkers of different nationalities, both in Italy and in other countries, to explore any cultural differences in pictogram comprehension. In addition, the participants we studied were a small sample employed in a specific geographical area, due to the high demands in terms of time and resources typically required by this kind of research[65] and to the particular workforce considered, which is spread across the region and has different work schedules. Another limitation concerns the small number of pictograms included in the study. Considering that the meetings were conducted on the farms during the working hours, the choice to investigate only 4 of the 12 pictograms analyzed in previous studies on local populations of Italy and Pennsylvania was due to time constraints, considering that each interview

took time to provide in-depth information regarding participants' viewpoints of the specific topic, as inherent in qualitative research.[65]

Furthermore, even if participants had been previously exposed to the investigated pictograms during the compulsory safety training, we did not have any control over how the training was performed. Future research should develop different experimental training sessions involving migrant farmworkers from different countries to understand which training methods are the most effective.[66] Moreover, in this study, the factor of familiarity (the frequency with which a sign has been encountered, as defined in Chan and Ng[18]) could not be sufficiently evaluated because we knew that the participants had already seen the pictograms during the training course, but participants were not asked whether and how often they had seen those pictograms in their workplaces. Finally, the pictogram features of concreteness, complexity, meaningfulness and semantic closeness may be assessed directly by means of a rating scale[18] to quantitatively evaluate the role played by each variable in affecting users' comprehension and to facilitate the process of participatory safety pictograms redesign with workers.

Conclusions

Migrant workers employed in the agricultural sector report a high rate of accidents. Safety pictograms play a key role in informing users about the residual risks from agricultural machinery, and they are supposed to be easily comprehended by all users. The present study showed that safety illustrations based on conventional graphics do not necessarily convey the correct and comprehensive meanings to individuals from different cultures. The migrant Pakistani farmworkers involved in the investigation did not have a complete knowledge of safety pictograms, even though they were previously exposed to them during the mandatory OSH training. This issue may be addressed by designing training programs tailored to migrant workers[67] stressing the topic of safety pictograms.[50]

A further step would be to improve the immediate comprehension of pictograms among migrant workers by redesigning them. Indeed, several features of the pictograms may influence

workers' comprehension and should therefore be addressed when developing cross-cultural safety pictograms, but no design guidelines are available to guarantee that perfect pictograms will emerge from the design process.[68] Hence, future studies should investigate and test safety pictogram comprehension among workers from different ethnic groups and highlight what differences, or similarities, exist between their interpretations of the same symbols. Thus, through a cross-cultural and worldwide user-centered design, it could be possible to develop suggestions to design safety pictograms that are more comprehensible among all users.

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