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RESEARCH ARTICLE

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User-centred design to promote the effective use of rear-mounted foldable roll-over protective structures (FROPSs): prototype evaluation among novice and expert farmers

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Abstract

Aim of study: We tested the perceived quality in use of a prototype of a handling supporting device, developed through a user-centred design process intended for rear-mounted foldable rollover protective-structures (FROPSs).

Area of study: The study was performed in the Province of Cuneo, which has the largest number of farms and the highest share of utilized agricultural area (UAA) in Piedmont Region, NW Italy.

Material and methods: Three groups of users, novice-novice (NN), novice-expert (NE) and expert-expert (EE) were asked to raise two rear-mounted FROPSs: a traditional one and a second one equipped with a supporting device which consisted of a gas spring and a rod. A questionnaire has been used to record the perceived quality in use of both FROPSs (effort, physical discomfort, temporal demand and ease of use) and perceived usefulness and attitudes toward the adoption of the supporting device.

Main results: All groups reported less physical effort, more stable postures, higher ease of use in handling the FROPS equipped with the supporting device; NN users, in particular, declared to be willing to adopt the supporting device in the future on their tractors when commercially available.

Research highlights: Previous studies reported discomfort in operating the FROPS as the main cause of its improper use. A solution to improve FROPS reachability was developed and tested with users. Benefits were perceived by both novice users and expert users.

Additional key words: agriculture; ergonomics; human-machine interaction; safe behaviour; foldable ROPS; user-centred design (UCD).

Abbreviations used: EE (expert-expert); FROPS (foldable rollover protective structure); NASA TLX (task-load index); NE (novice-expert); NN (novice-novice); PTO (power take-off); RAG (Research Advisory Group); ROPS (rollover protective structure); UCD (user-centred design)

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Introduction

Agriculture is one of the most hazardous sectors in terms of fatal and non-fatal accidents (Abubakar *et al.*, 2010; Pessina *et al.*, 2016; Fargnoli & Lombardi, 2020). The accidents are mainly caused by machinery and mostly involve tractors (Robert *et al.*, 2015), with tractor rollover as one of the most common causes of fatal occupational injuries (Arana *et al.*, 2010; Robert *et al.*, 2015; Pessina *et al.*, 2016; Darçın & Darçın, 2017). Rollover protective structures (ROPS) such as cabs, roll-bars and frames have been developed to avoid or limit the risks to the driver resulting from tractor rollover (OECD, 2020a).

Cabs and frames refer to a barrier that consists of a hard surface on the top and on the sides, which surrounds the occupant of the tractor when seated at the driving station. Cabs are closed on the sides by glasses and protect the driver also from outside elements such as adverse weather conditions and dust. Whereas the roll-bar frames are generally composed by two lower steel components, one for each side of the tractor, fixed by supports to the gearbox when the protective structure is mounted in front of the driving station, or to the rear axle when it is mounted on the back of the driving seat respectively, and an upper inverted U-shaped folding steel tube. Front- and rear-mounted roll-bars are generally fitted on narrow-track tractors (tractors having the distance between the centreline of two wheels on the same axle less than 1150 mm) with a maximum permitted unladen mass of 3500 kg (OECD, 2020b,c). But they can find application also on standard tractors (tractors having the distance between the centreline of two wheels on the same axle greater than 1150 mm) without any limitation for the unladen mass (OECD, 2020a).

Roll-bars can be fixed or foldable. The folding version of the roll-bar (Foldable, Rollover Protective Structures, FROPSs) has been designed and adopted to allow tractors to operate in low overhead clearance conditions, such as low canopy orchards and vineyards, greenhouses and buildings, such as poultry farms. FROPS improve tractors' mobility, transport and storage possibility. When FROPS is in front of the driver station, it can be manually folded frontward, or rearward when FROPS is at the rear of the driving seat. ROPS and FROPS provide the space for a clearance zone large enough to protect the driver when seated (NIOSH, 2009) and, when associated with the seatbelt, are able to significantly reduce the fatalities and serious injuries when a tractor overturn or rollover occurs (Myers & Pana-Cryan, 2000; Cavallo *et al.*, 2014). In Scandinavian countries, where ROPSs have been first made compulsory, a significant decline in tractor overturning fatalities was reported (Thelin, 1998). Since 1980 such protective structures are mandatorily fitted on tractors put on the market in most of the developed countries (Cavallo *et al.*, 2015).

Because of these benefits, FROPSs have been increasingly proposed by manufacturers on their tractors and appreciated by end-users for application in different contexts and countries. However, a high rate of injuries occurs during tractor rollover due to the widespread habit of removing or leaving FROPSs in the folded-down position (Hoy, 2009; Fargnoli *et al.*, 2018). This unsafe behaviour seems to be related to issues in FROPSs manual handling, which is considered a time-consuming and/or an arduous operation (Khorsandi & Ayers, 2018). Previous research investigating such topic among end-users reported challenges concerning FROPS reachability (Micheletti Cremasco *et al.*, 2020), pointing out that the quality of the human-machine interaction is affected by both operators' characteristics and tractors' dimensions. Since the FROPS has to be manually operated, the issues concerning postures, comfort in use and reachability assume a particular relevance when the dimension of the tractor preclude FROPS operation from the ground, which is often the case of rear-mounted FROPS fitted on standard tractors. These aspects, together with users' variability have to be considered to design and develop an effective technical solution that can be easily implemented by manufacturers and accepted by the users, regardless their age, gender and physical characteristics (Pessina *et al.*, 2016; Micheletti Cremasco *et al.*, 2021). This focus on the user represents the key element of the user-centred approach to systems design and development.

The user-centred design (UCD) approach can successfully contribute to tackle this issue helping to better understand real users' needs and behaviours and develop targeted and effective solutions based on users' requirements (Bevan & Curson, 1998; ISO, 2010) (Fig. 1). The UCD process has been widely adopted to achieve users' satisfaction, enhance ease of use and improve systems' safety and quality (Giacomin, 2014). One of the key aspects of this approach is the involvement of users in the entire design process, from the definition of the requirements the system should satisfy, to the evaluation of the prototypes developed based on these requirements. The perceived quality in use of the prototype is then evaluated in terms of usefulness, comfort, avoidance of harm, and effectiveness, to implement targeted corrective measures on the final version of the system. This iterative process represents the key to reduce products and systems failure (van der Panne *et al.*, 2003; Vredenburgh & Zackowitz, 2009). This approach has been successfully applied in different contexts such as medical (Grocott *et al.*, 2007; Privitera *et al.*, 2015), maritime (Österman *et al.*, 2016; de Vries *et al.*, 2017), aviation (König *et al.*, 2012) and industrial sectors (Venturi *et al.*, 2006) but also in the design of academic teaching courses (Kahraman, 2010), digital and smart tools (Cha & Ahn, 2019; Demirbas & Timur Ogut, 2020) and interfaces (Wong *et al.*, 2012; Martin *et al.*, 2018).

In the agricultural context, the importance of involving farmers in the different UCD phases is recognised as crucial in the definition, design or implementation of innovative and safe products, machinery and systems (Lindblom *et al.*, 2017; Oliver *et al.*, 2017). Rose *et al.* (2018) highlighted the essential role of UCD in the realization of decision support systems (DSS) dedicated to agriculture to improve farmers' decisions, productivity and sustainability. Involving users during systems design and evaluation has proven to be effective in increasing trust (Guillaume *et al.*, 2016) and useful to know farmers' decision making (Rossi *et al.*, 2014). Haapala (2019) highlighted the benefits of UCD and of involving different stakeholders in the design of agricultural machinery to reach satisfaction, ease of use and acceptability, while saving resources and time of iterations with significant advantages for both users and manufacturers. Furthermore, Haapala (2019)

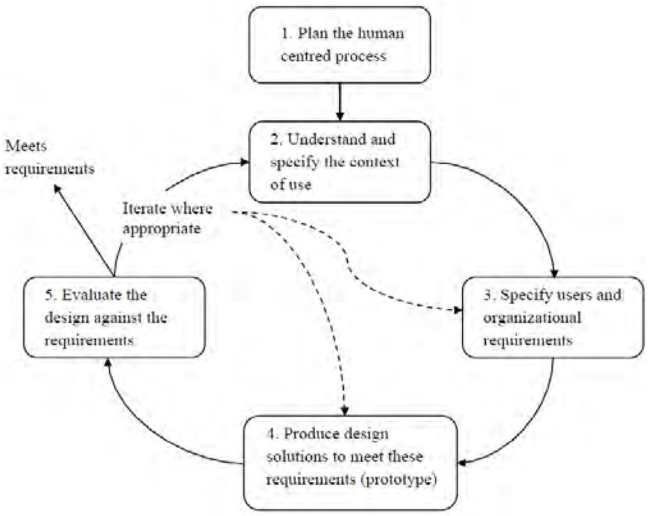

Figure 1. User-centred design phases. Adapted from Bevan & Curson (1999) and ISO 9241-210 (2010).

reported that involving farmers with different skills and competencies has a unique value in the innovation process and confirms the importance of tackling issues by sharing experiences and knowledge; as an example, he reported that testing the prototype of a new combi-drill with end-users and researchers in different circumstances has boosted the innovation process and optimised users' satisfaction and ease of use.

In order to provide Sri Lankan farmers with essential information for their working activities in a fast, easy and targeted way, Walisadeera *et al.* (2013, 2015, 2016) applied the UCD to the development of a mobile based information system. The involvement of farmers from the initial phases of the development, investigating their needs, to the evaluation of the designed system, provided context-specific information. Ortiz-Crespo *et al.* (2020) obtained the same results testing a digital advisory service for farmers in Tanzania.

Considering safety issues, researchers highlighted how applying UCD to optimise or design a product can increase safety, comfort, user acceptance, and intention to adopt it. In particular, Mohd Yusoff *et al.* (2014) proposed a new ergonomic chisel to reduce oil palm workers' discomfort and awkward postures considering users' characteristics, needs and limits. Results highlighted the lack of correspondence between tools dimensions and users' measurements and needs that drove the researchers to design a new tool based on real users' dimensions aiming to decrease discomfort and postural overload. In a study involving a group of male oil palm workers information and motivations that underlies the limited use of working hard hats was collected to develop a new one (Mohd Shukoor *et al.*, 2018); results reported crucial information for the development of a user-centred new hard hat, according to real users' needs and perceptions (Mohd Shukoor *et al.*, 2018). This approach increased hat comfort and encouraged its adoption.

A user-centred approach has been adopted in agriculture also for the development of safety training materials and manuals (Caffaro *et al.*, 2017a; Cutini *et al.*, 2017; Vigoroso *et al.*, 2020). Vigoroso *et al.* (2020) in their study developed a new visual training material intended to overcome the language barriers among farmworkers, by actively involving a group of trainers and groups of both local and migrant farmworkers from the early stage of the research. In the final evaluation of the developed material, the use of photographs and graphics in cartoon style proved to meet the end users' needs and requirements, being an effective solution to increase safety knowledge, satisfaction and to reduce the perceived effort during the training lectures. Whereas, Cutini *et al.* (2017) investigated farmers' habitual use of safety and maintenance manuals, and what they expect from communication on health and safety. Groups of users were involved in several workshops and focus groups sessions on drafting and defining the contents of the new safety manual communication and its attractiveness, comprehensibility and acceptability.

It has been recognized that participatory UCD is profitably adopted in rural development and agricultural research for innovations development, natural resource management and agricultural systems evolution (Neef & Neubert, 2011). However, there are few concrete examples of innovations that have been developed by farmers and researchers working together (Hoffmann *et al.*, 2006).

Based on the previous considerations, the aim of the present study was to test the perceived quality in use of a prototype of a technical solution to support rear-mounted FROPS handling, developed by means of a UCD process, compared with a traditional non-supported FROPS. Users' perceptions of comfort, time demand, effort, effectiveness, usefulness and intention to adopt the proposed solution were assessed, to develop a solution able to encourage the operators to properly handle the rear-mounted FROPS.

Material and methods

Overview of the prototype UCD

The prototype of the new solution has been developed starting by identifying the critical aspects in rear-mounted FROPS handling and real users' behaviours (Bevan & Curson, 1998; ISO, 2010). As reported in a previous study (Micheletti Cremasco *et al.*, 2020), in the early stage of the research a group of twenty expert farmers (age: mean=49.24, SD=11.49; years of experience: mean=23.13, SD=17.66) were interviewed and observed during the interaction and handling of a rear-mounted FROPS, to evaluate the frequency of its operation, possible sources of discomfort in handling under real conditions of use and suggestions and requirements for improvement (corresponding to 1st, 2nd and 3rd of UCD phases summarized in Fig. 1). The results showed that several of the interviewed farmers would have welcomed the addition of a handle on the roll-bar to easily reach the highest points of the rear-mounted FROPS (Micheletti Cremasco *et al.*, 2020). Indeed, when available, some of the shorter participants used improvised tools already mounted on the tractor, such as the mirror shaft (see Fig. 2), as a spontaneous strategy to improve the reachability of the foldable component of the protective structure. These participants also reported higher levels of effort in rear-mounted FROPS operation and showed awkward and risky postures when climbing on some parts of the tractor to reach the foldable frame.

To increase the reachability from the ground of the upper foldable part of the FROPS and to reduce effort and awkward postures, the prototype of a FROPS handling supporting device was developed and manufactured by the research group (phase 4), (see Fig. 1). The prototype consisted of a gas spring fitted on the rear-mounted FROPS left pivot point and a rod with a padded handle mounted on the right side of the foldable roll-bar (Fig. 3). In detail, the rod had a length of 800 mm (including 160 mm of padded handle on the ending part), whereas the gas spring used had a maximum arm length of 350 mm and a force of 350N. The present study focuses on the testing of the quality in use of the prototype and on collecting suggestions to further improve the developed solution (phase 5) (Fig. 1).

Sample involved in the prototype evaluation

Twenty-four male participants (mean age=31.08 years, SD=14.32) took part in the study. Based on Faulkner (2003), they were subdivided into three groups based on the levels of participants' experience with tractor and Foldable ROPS: Novice-Novice users (NN, *i.e.* operators who do not had previous experience with tractors equipped with FROPSs), Novice-Expert users (NE, *i.e.* operators who had previous experience with tractors fitted with front-mounted FROPS) and Expert-Expert users (EE, *i.e.* operators who had previous experience with tractors fitted with rear-mounted FROPS).

Previous studies have shown that consulting expert users can be useful for generating a complete list of problems, while novice users are helpful in identifying the most severe issues (Sauer *et al.*, 2010; Caffaro *et al.*, 2017b). In an attempt to collect as much information as possible on the prototype, agricultural operators with different levels of expertise in FROPS handling were involved in the study.

Figure 2. Farmer while using the mirror shaft to overcome the reachability issue when raising FROPS.

Instruments

In the present study, the perceived quality in use of the prototype of the rear-mounted FROPS supporting device was assessed using two prototypes of tractors (Fig. 3a) equipped with the protective structure and developed in accordance with measures and dimensions of tractors observed in the on-field previous investigation (Micheletti Cremasco *et al.*, 2020), to simulate the real tractor obstructions. In both tractor models, the power take-off (PTO) guards and the lift arms used as supports for the feet were also simulated, to replicate the supports for the feet used by farmers to operate the rear-mounted FROPS (as observed in Micheletti Cremasco *et al.*, 2020) while ensuring that the task was carried out safely.

One prototype was equipped with a traditional rear-mounted FROPS (without any additional device), while the second prototype had a modified protective structure equipped with the handling supporting device (Figs. 3b and 3c). The dimensions and position of the rod has been defined to fulfil the ergonomic requirements as described in the handling of rear-mounted FROPS (OECD, 2020b) with the operator standing on the ground, behind the tractor. Participants' postures and behaviours were video recorded while performing the FROPS handling tasks. The video recorded from the side view were analysed.

The perceived quality of use of both FROPS was assessed by means of an ad-hoc questionnaire developed starting from the NASA Task-Load Index (TLX) (Hart and Field California Lowell Staveland, n.d.), and adjusted for this specific task. Participants were asked to rate their agreement (from 1=not at all agree to 4=totally agree) with different statements regarding the effort in operating the FROPS (1 item), physical discomfort (4 items), temporal demand (1 item) and ease of use (2 items) (see Table 1). The questionnaire for the FROPS equipped with

a) b) c)

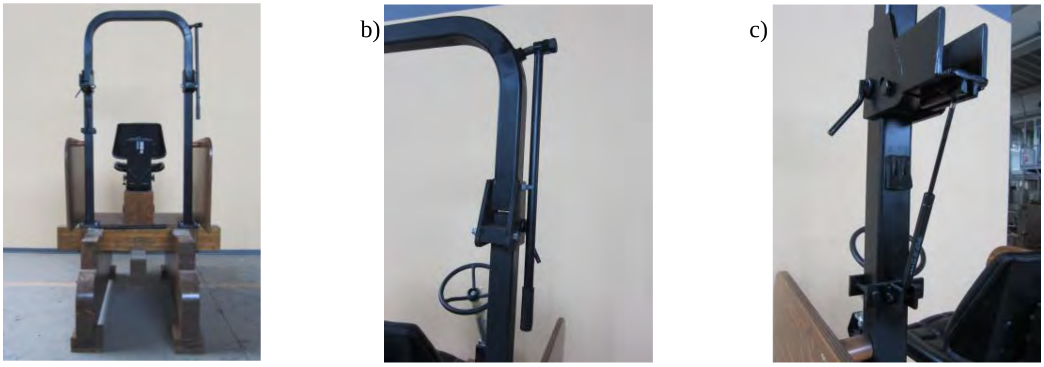

Figure 3. The rear-mounted FROPS prototype equipped with the supporting device (a), which consisted of a rod mounted on the right side of the foldable roll-bar (b) and a gas spring fitted on the FROPS left pivot point (c).

the supporting device, included an additional section related to the perceived usefulness and intention to adopt the proposed solution (four items, from 1=not at all agree to 4=totally agree). An open-ended question regarding possible improvements of the prototype to make the rear-mounted FROPS handling easier closed the questionnaire (see Table 2).

Procedure

The study was carried out in the province of Cuneo, which has the largest number of farms and the highest share of Utilized Agricultural Area (UAA) in Piedmont Region, North-western Italy (ISTAT, 2013). For this reason, and because it has a large percentage of hilly and mountainous agricultural areas, the province of Cuneo reports the highest number of tractor-related accidents within the Piedmont region (Basso *et al.*, 2010). Participants to the study were recruited with the support of tractors' dealers and safety training companies. The study was conducted at the CNR-IMAMOTER (Institute for Agricultural and Earthmoving Machines of the National Research Council of Italy) facilities, where participants were asked to gather. No incentives were given for the participation in the study.

Participants were invited to raise both the traditional and the modified rear mounted FROPS and after each operation they were asked to complete its respective questionnaire section. The participants were asked to perform the task from behind the tractor while keeping the three-point contact with the machine recommended by the literature to ensure their safety (HSE, 2003); apart from this, no movement constraints were imposed on the participants. To avoid habituation and learning effects, the participants performed the operation one by one. Furthermore, half of them were randomly selected to operate the traditional protective structure first, while the others started with the modified one.

All the participants were informed on the nature of the study, signed an informed consent before participating in the study and their right to data and privacy protection. The study was approved by the Research Advisory Group (RAG) of the CNR-IMAMOTER.

Data analysis

Descriptive statistics were calculated for all the variables of interest for all three groups of participants. Due to the small sample size and not normally distributed

Table 1. Questions used to assess the perceived quality in use of both rear-mounted FROPS (traditional and supported).

Category	Question ID	Item
Effort	Q1	FROPS was heavy
Physical discomfort	Q2	I had to adopt awkward postures
	Q3	It was difficult to find a support for the feet
	Q4	It was difficult to find a support for the hands
	Q5	I was afraid of getting hurt
Time demand	Q6	It was time-demanding
Ease of use	Q7	I immediately knew how to do it
	Q8	I felt awkward while performing the task

Table 2. Questions used to assess the perceived quality in use of both rear-mounted FROPS (traditional and supported).

Category	Question ID	Item
Perceived usefulness	Q9	The gas spring is useful
	Q10	The rod is useful
Intention to adopt	Q11	I would like to have the gas spring on the tractor
	Q12	I would like to have the rod on the tractor
Users' suggestions	Q13	Criticalities and/or suggestions for improving the developed device (open-ended question)

data (Shapiro Wilk test <0.05), non-parametric statistics were computed to compare the three groups. A preliminary Kruskal-Wallis H test was performed to check for any significant difference in stature between the three groups considered, since previous research highlighted that the users' stature represents a relevant factor which can influence the postures adopted during the rear-mounted FROPS manual handling (Micheletti Cremasco *et al.*, 2020). No significant differences emerged ($H(2)=0.806$, $p=0.668$). To investigate the differences among the three groups of participants in their ratings on the perceived quality in use, a Kruskal-Wallis H test was performed for each item of both the traditional and the supported prototypes of the rear-mounted FROPS. A paired-samples Wilcoxon test was then used to investigate the possible differences between handling the traditional protective structure and the supported one within each group of participants (*i.e.*, NN, NE, EE). The Kruskal-Wallis H test was finally computed to analyse the between-groups differences in the perceived usefulness and intention to adopt the supporting device.

Results

All three groups of participants reported an improvement in handling the modified rear-mounted FROPS compared with the traditional one in all the aspects investigated: less physical effort, more stable postures and higher ease of use (Fig. 4). Users' perception regarding the greater difficulty to find support for the feet and the hands-on the traditional FROPS were mirrored by the observations, which recorded many participants climbing on different parts of the machine to operate the folding roll-bar in the traditional FROPS, as it can be seen in Fig. 5. Seventeen out of 24 participants raising the traditional rear-mounted FROPS climbed on the simulated lower lift arm or PTO guards to reach and handle the folding bar, whereas all the participants operating the supported FROPS grabbed the rod and performed the task by maintaining their feet on the ground.

With regard to the levels of participants' experience with FROPS, no significant differences were found between the three groups of participants for each item investigated, both for the traditional rear-mounted FROPS and for the one equipped with the supporting device. However, it was noticed that the EE users reported more critical ratings for both types of rear-mounted FROPS. Whereas, considering the differences within each group of participants in handling the traditional FROPS and the supported one, some significant improvements were noticed from the traditional protective structure to the modified one: in particular, compared with the traditional rear-mounted FROPS, the group of NE users reported a significantly reduced effort in handling the supported prototype of the protective structure (Q1, FROPS was heavy) ($Z=2.00$, $p=0.046$), while the NN users felt significantly more at ease in operating the supported FROPS (Q8, I felt awkward while performing the task) ($Z=2.00$, $p=0.046$). No significant improvements were reported for EE users between the traditional and the supported FROPS.

Regarding the perceived usefulness of the supporting device and the opportunity to fit it on tractors, the results pointed out that both the rod and the gas spring were perceived as useful in helping the raising operations. A sum score of the perceived usefulness and intention to adopt the whole system was computed by adding the responses given by each participant to Q9 and Q10 (perceived usefulness) and to Q11 and Q12 (intention to adopt). The whole supporting system was found to be useful especially by NE users, followed by EE and NN users, reporting a mean sum score of 7.38, 7.13 and 6.38, respectively. Similarly, the NE users were more willing to have the supporting device adopted, followed by the EE and NN users, reporting a mean sum score of 5.75, 6.5 and 5.25, respectively. Detailed information is reported in Fig. 6. When comparing the three groups of participants, the Kruskal-Wallis test did not show any significant difference between NN, NE and EE users either in the perception of usefulness or intention to adopt the supporting device, considered both as a whole and in each of its components separately.

Regarding the suggestions given by the participants to further improve the device and make the rear-mounted FROPS handling easier, the NN users provided the majority of responses (Table 3). On the opposite, the EE reported the fewest number of comments. Only one NN user reported that "the proposed device seems to be an appropriate effective solution and it allows me to speed up the FROPS operation, compared with the traditional manual handling one". The users' suggestions could be

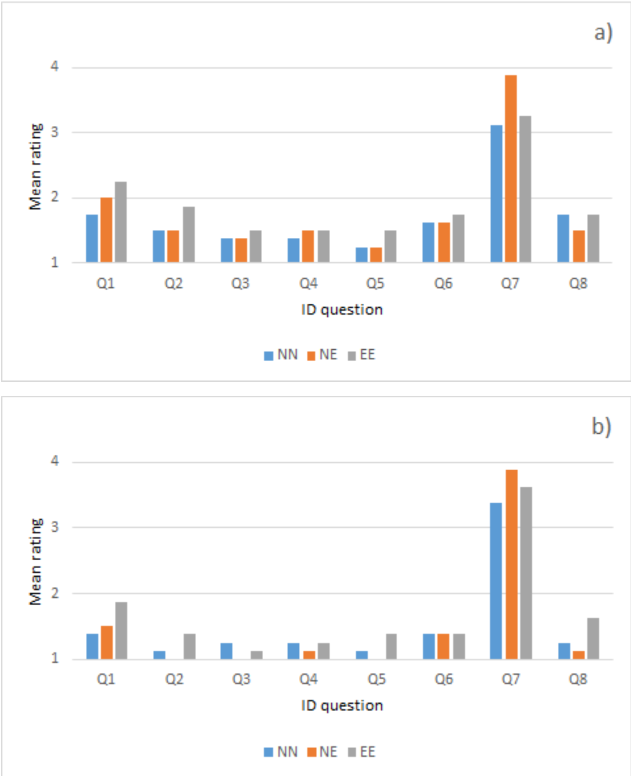

Figure 4. Mean ratings given by the participants to the different aspects of prototype quality of use: (a) for the raising task with traditional rear-mounted FROPS and (b) for the raising task with rear-mounted FROPS equipped with the supporting device. Questions and their respective ID are listed in Table 1.

grouped into three categories referring to three FROPS components: the pivot pin, the gas spring and the rod.

Concerning the pivot pin at the pivot point required to be removed and inserted to fold and put the protective structure in position, NN and NE users suggested "to improve the management of the pivot pin", "using something to facilitate the inserting or extracting the pins during the task" and "using something that allows placing the pins next to me, so that I do not have to use an improvised support for them [because they can fall down and/or I can lose them]". The EE participants did not report any specific suggestion.

Concerning the gas spring device, the EE users suggested adding a second gas spring also on the right side of the protective structure; whereas the NN generally suggested that "it can be improved since it is difficult to manage at the beginning of the movement" and "gas spring seems to be too thin; I think it can be improved".

Most suggestions provided by the participants concerned the rod. These latter suggestions can also be subdivided into three main categories related to rod length, grip, and position. In detail, both NE and NN users reported that it could be useful "to have a longer rod, to facilitate the handling also using both hands". Some NN participants expressed the need "to have a shaped handle" and the need "to improve the grip of the rod".

Finally, opposing and diverse suggestions were reported about its position by all NN participants: "I would place the handle higher", "I would place the handle lower", and "I would place the handle on the other side". Also in this case, the EE participants did not report any specific suggestion.

Discussion

To our knowledge, most of the previous studies investigated issues related to front-mounted FROPS manual handling (Pessina *et al.*, 2016; Franceschetti *et al.*, 2019), whereas few previous studies focused on issues

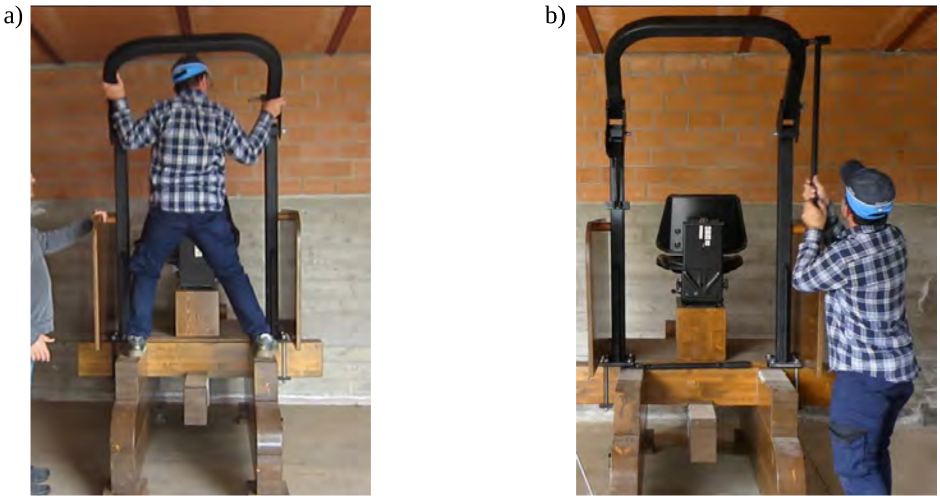

Figure 5. Novice-novice (NN) participant (*i.e.*, operator who do not have experience with tractors equipped with FROPS but only with cabs) observed while raising the rear-mounted FROPS: as it can be seen, for the traditional FROPS the participant climbed on the simulated lift arms to reach and operate the folding roll-bar (a), whereas, for the modified FROPS, equipped with the supporting device, the raising task was performed by standing on the ground (b).

related with the manual operation of rear-mounted FROPS, mainly resorting to a technical engineering approach for the development of mechanical solutions (Ayers *et al.*, 2019; Franceschetti *et al.*, 2019; Guzzomi *et al.*, 2019; Micheletti Cremasco *et al.*, 2020). However, user-centred issues during rear-mounted FROPS operations have recently received increased attention (Ayers *et al.*, 2018; Franceschetti *et al.*, 2019).

The results of the present study showed that adopting a user-centred approach to identify criticalities and potentialities in the development of a new device and testing the perceived quality in use of such a device, can help to make more appreciated and comfortable changes. The results also highlighted the usefulness of involving users with different previous experience to obtain a wider range of suggestions in prototype evaluation. Indeed, fitting rear-mounted FROPS with a rod with a padded handle and gas spring, to improve reachability and reduce effort demand allowed all the participants to perform the raising task by standing on the ground. Therefore, the adoption of the proposed solution to facilitate rear-mounted FROPS operation may help to promote safer users' behaviours and reduce the risk of falling from the tractor, which has been observed in a previous study when participants climbed on muddy or wet parts of the machine as an inappropriate support for the feet to operate the protective structure (Micheletti Cremasco *et al.*, 2020). The use of the rod allowed participants to avoid awkward postures, making it also immediately clear to the user how to interact with it to operate the FROPS (*i.e.* providing an affordance (Norman, 1988), also for NN users. One of the main problems raised by most of the participants was the force needed to overcome the initial spring resistance during its extension phase. Despite this, users recognized the benefits that the whole system developed provides, since it highly facilitates the protective structure raising task.

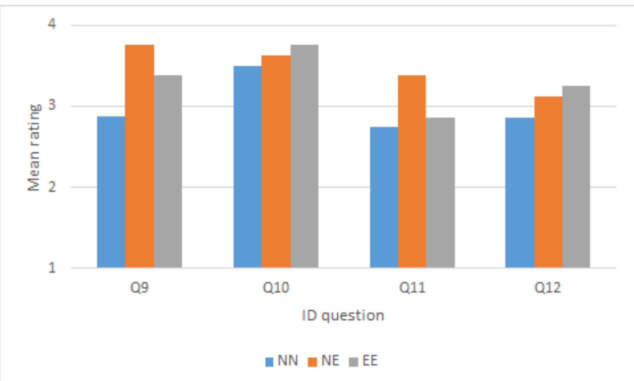

Figure 6. Mean ratings of perceived usefulness and attitudes toward adoption of the supporting device, considering the gas spring and rod separately. Questions and their respective ID are listed in Table 2.

Based on the results of this study, the following considerations can be pointed out:

- Novice-novice (NN) users reported a significantly higher level of ease of use of the new supporting device; they appreciated it and they would have been willing to find it adopted on tractors in the future;
- Novice-Expert (NE) users showed a significant reduction in the perceived effort when adopting the new supporting device and they were more inclined to use the new device. Probably, it was because they were aware of the difficulties related to rear-mounted FROPS handling and they find it a fastest and a less demanding solution;
- Expert-expert (EE) users reported an improved quality of use of the supported rear-mounted FROPS for all the considered variables, but not so remarkable compared to the others; this may be due to the fact that expert-expert behaviour is more rooted (Brorström & Siverbo, 2004) and it is difficult to understand immediately all the advantages and benefits of the solution proposed.

The results concerning NN users are encouraging since these users represent an important market segment on which tractors' manufacturers can focus to expand the adoption of rear-mounted FROPS. Indeed, novice users may particularly benefit from supporting systems if rear-mounted FROPSs are already equipped with the developed device.

On the other hand, the pattern of responses of EE users raises some considerations on the fact that technical improvements alone could not be sufficient to solve safety issues in the human-machine interaction (Stahre, 1995), especially for those users who have already developed routine interaction behaviours (Brorström & Siverbo, 2004). Changes in technical features or a new design, should be supported by targeted information and training activities to promote the correct behaviour and use of the proposed solution (Caffaro *et al.*, 2018).

The device developed in the present investigation resulted being an excellent design solution: all the participants rated the use of the device as immediately understandable, as reported by Popovic (2003), who reported that design should facilitate the utilisation of a product and allow an intuitive interaction with it. Facilitating the machinery operations it is possible to avoid situations that may injure the farm operator/farmworkers (Caffaro *et al.*, 2017c). Moreover, the encouragement of proper rear-mounted FROPS handling, can have a positive social impact in a short time among users, allowing the dissemination of good behavioural practices (Thaler & Sunstein, 2008).

Although the sample is limited in size, the present study is still of interest, since it represents a first analysis of the intention of real users to adopt a new device to use the rear-mounted FROPS properly. Despite this

Table 3. Suggestions reported by the three groups of users.

FROPS elements to be improved	Group		
	NN	NE	EE
pivot pin	2 suggestions	2 suggestions	
gas spring	5 suggestions		1 suggestion
rod: length	2 suggestions	2 suggestions	
rod: grip	4 suggestions		
rod: placement	7 suggestions		

limitation, the present study is supported by the assumption reported by earlier studies (Faulkner, 2003), in which it was argued that just five participants could reveal about 80% of all criticalities in the use of a product. Moreover, in accordance with Faulkner (2003), this study confirms that novice users are able to identify a larger number of issues when interacting with a system.

In the present study, we included only male participants based on the predominance of male workers among the Italian farming population (EC, 2020). However, this choice did not allow us to investigate the effects of gender. Considering the recent increasing participation of women in the agricultural sector (De Schutter, 2013), female perceptions and behaviours in FROPS operation should be taken into account in future studies.

Finally, we acknowledge that the present results cannot be considered as conclusive since the quality in the use of the supporting device developed for this study could be further investigated with participants with different biomechanical, dimensional, and functional characteristics (*e.g.*, aged people or migrant workers), whose presence is increasing among the workforce population of the developed countries (Ilmarinen, 2006), and may then undergo further changes; however we strongly believe that the results of this study showed that developing technical solutions by means of an active involvement of the target users can lead to a better quality in the human-machine interaction.

The involvement of users in the early phase of the design and in the evaluation of a prototype has proved to be useful for the development of supporting devices to encourage the correct and safe use of rear-mounted FROPS. The results of the present study pointed out that UCD can lead to an improved technical solution not only through the assessments of reachability and biomechanical comfort, but also in evaluating aspects of ease of use, perceived effectiveness and intention to adopt. Providing an alternative option that allows the operators to perform the task more easily and safely, could represent a useful starting point to change the operators' behaviour and make this change as their “default” behaviour. In fact, involving the user in the user-centred design helps not only to pursue technical and instrumental improvements for the machine and for the protection of workers in human-machine interaction, which is so critical in agriculture, but it also helps to increase the safety culture and accompanies the adoption of safe behaviours. The more active participation of novices, is encouraging and it helps to imagine wider spaces for collaboration between the manufacturers and the users, for the improvement of knowledge and innovation to protect the individuals and promote the performance of the whole working system.

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