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Collaboration and Co-Creation in Industry 5.0: User-Engagement With Industrial Operators Through Co-Creation Workshops

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ABSTRACT

Industry 5.0 is characterized by human-centric designs and solutions. This implies that the creation and implementation of new technologies in industrial tasks should involve and engage the workforce at every stage of development. An effective method of workforce engagement are co-creation workshops - collaborative sessions designed to understand the needs and preferences of the end-users of new technology. Operator engagement through such workshops can provide valuable feedback for the design of new technology as well as boost operators' acceptance of the new smart production systems. The following paper presents the methodology and findings from co-creation workshops conducted by the EU-funded project "CONVERGING", in four use cases with factory operators. The workshops enforced a three-step protocol combining discussions and hands-on design tasks with the industrial operators. The workshops aimed to capture the operators' experiences with the current task, expectations from smart assistive technologies, and their opinions on the CONVERGING solutions. The findings that emerged from the workshops are discussed for each use-case.

Keywords: Industry 5.0, Human-robot collaboration, User-centred design, Co-creation workshops, Smart technology, Robot trust, Robot anxiety

INTRODUCTION

The aim of Industry 5.0 is to centralize the needs and interests of human workers and develop production systems by prioritizing workers' wellbeing. While Industry 4.0 saw the creation of cyber-physical systems with the implementation of digital twins, machine learning, cloud technology, etc. (Maddikunta et al., 2022), the existence of the human operator in these production systems was left vastly unconsidered (Mitchell et al., 2021). In Industry 5.0, the human element is brought back to the center of these cyber-physical production systems, wherein the human operator is assisted by and collaborates with smart technology and machinery. For these systems to centralize the human operator, the development, design, and implementation of the smart technologies must involve the industrial operators at every stage.

This engagement of the of technology's end-users in the design process is a key tenet of the user-centered design approach. In this design approach, the needs of the end-users of the technology are captured in an iterative process to serve as feedback to the technology developers. Research has shown that user-centered approaches in design increases user-acceptance (Pais et al., 2022). Involving the operators in the development of new smart production systems can boost the operators' acceptance and openness towards the new technology alongside centralizing them in the design process. There are different approaches to capturing this feedback from the end users such as observations, in-situ interviews, focus groups and workshops (Rodriguez et al., 2023). While interviews and focus groups are effective methods for achieving user feedback, they are not very conducive for the generation of new ideas and insights outside pre-determined discussion points or questions (Benson et al., 2021). On the other hand, workshops have been found to be beneficial for not only capturing the needs and interests of end users, but also for enabling a collaborative and innovative environment with them. Specifically, co-creation workshops are effective means of fostering mutual learning and exchange of ideas between the developers and end-users.

Co-creation workshops are sessions designed to involve end-users of a product/service in its development. The aim of co-creation is twofold – firstly, to capture the needs, requirements, and expectations of the end-users, and secondly, enable knowledge creation and innovation with the end-users thereby making them co-designers (Kristensson et al., 2008). Co-creation workshops typically encourage the end-users to develop new ideas, discuss their current experiences with the product/service and their expectations for its future implementations. These steps are conducted through a combination of methods. The workshops often use brainstorming sessions, and semi-structured or unstructured group interviews, that are moderated or guided by the researcher. These discussions are oriented towards capturing various stakeholders' experience with a product or service and their response to a prototype, ideas and solutions (Agarwal et al., 2022; Albitres-Flores et al., 2024; Jansma et al., 2022; Slomian et al., 2017). Very often, co-creation workshops include hands-on design tasks where the participants are given an opportunity to ideate and design their versions of the product or service. Previous studies have implemented this through drawing and sketching (Benson et al., 2021) and creating models with toys (de Saille et al., 2022).

Research that has employed co-creation methods have found them to be effective for understanding consumer attitudes and perceptions (Benson et al., 2021), exploring consumer backgrounds that affect use of a product (Kristensson et al., 2008), determining key features expected from an application (van de Riet et al., 2024) and identifying barriers to accessing a service (Agarwal et al., 2022).

User-design approaches to study human-robot interaction in service robotics, have employed co-creation methods with design activities using Lego blocks. In these studies, participants build models with the Lego blocks to illustrate their visions of service robots and human-robot interactions, followed by discussions of their models (de Saille et al., 2022; Simon et al., 2020; Tuomi et al., 2020).

In the domain of industrial human-robot collaboration, co-creation workshops have been previously used for the development of interfaces for human-robot interaction (Kohlgrüber et al., 2021). By introducing working prototypes of the robot to the operators, the robot designers gained valuable feedback about the robot's design, function, and tasks, while the operators in turn learnt how to operate the robot.

Co-creation methods were also used for developing and refining graphical communication signage used for industrial co-working with robots (Gwilt et al., 2018). This study involved employing a mix of surveys, interviews and design prototyping tasks that helped understand the employees' attitudes towards working with robots, and how graphical signage should be designed to facilitate acceptance of the robots.

Thus, co-creation workshops are effective opportunities to improve technologies being developed for industrial tasks as they can help ensure user-friendly designs alongside familiarizing the industrial operators to the new technologies. However, the use of co-creation workshops to engage industrial operators in the development human-robot collaborative systems is still sparse.

The following paper presents the methodology and findings from co-creation workshops conducted in four industrial use cases that are part of the EU-funded CONVERGING project. CONVERGING is an Industry 5.0 project that aims to develop and deploy smart production systems by integrating big data, AI, and collaborative robots in the automotive, white-goods, aerospace, and additive manufacturing industries. The project aims to introduce smart production systems while establishing a human-centered social industrial environment that maximizes user-experience, trust and safety. (*Home | CONVERGING | EU Funded Project*, n.d.).

METHOD

Participants

Participants in the workshops were factory operators working in the industrial tasks of manual sanding of dies (automotive industry – 4 male participants), support removal and surface finishing of additive manufacturing parts (additive manufacturing industry – 4 male participants), fuel tank inspection and maintenance (aerospace industry – 5 male participants) and electric hob assembling (white goods manufacturing industry – 4 female participants). Each workshop had participants with varying experience (between 5 to 25 years) and roles (interns, operators, and line/ human resource managers).

Procedure

Participants were invited by the use-case leader to join the workshops. Three workshops took place on-site in the factory, while one workshop took place virtually. The participants were introduced to the researchers, who began the workshop by providing an overview of the aims and activities of the workshop. They were informed about what they would be asked to do, their right to refrain from participation and withdraw, and the option to abstain from answering any questions that made them uncomfortable. The information and consent were translated by the use case leader. The workshop discussions were translated by the use case lead. Informed consent was recorded from participants on a separate recording. The workshops then commenced following the steps described in the following section.

Workshop Protocol

The workshops enforced a three-step process. The first step was a discussion with the operators to capture the enjoyable and challenging aspects of their jobs. The second step began with a discussion about smart assistive technology operators are aware of (such as collaborative robots and augmented and virtual reality) that could be incorporated into their industrial tasks. The operators were then provided with a set of design materials (listed in the materials section) and were invited to a hands-on creative activity to design their vision of a potential workspace with smart assistive technology. The third step was a presentation of the CONVERGING smart technology solutions, followed by revisiting the hands-on design activity where the operators redesigned their workspace in consideration of the CONVERGING solution. The new designs and feedback on the CONVERGING solutions were discussed further.

Materials

For the hands-on design activity, the participants were given a set of paper cutouts of graphics of a human, robotic and smart technology applications (single-arm robot, mobile robots AR headset, smart pen), industrial components (desk, cookers and cooker hoods, automotive parts, airplane parts, tool kits, raised platforms). They were also given A4 size papers, sketch pens, rulers, and glue sticks.

The CONVERGING solutions were presented to them through a power point presentation that contained slides of simulated graphics of the proposed future technologies.

The following questions were asked at various stages of the workshop (as explained in the workshop protocol) to guide discussion:

- What do you like about the task? What are its enjoyable or pleasant aspects?
- What do you dislike about the task? What are its challenging or unpleasant aspects?
- What are some smart technologies you are aware of? How do you think it could help you in your job?
- What do you think of the CONVERGING technological solutions? What are its strengths and weaknesses?
- How can these solutions be improved?
- What kind of training do you think you will need for working with the new technology?

FINDINGS

Automotive Industry

All operators agreed that the most enjoyable aspects of their work were challenging tasks that required them to demonstrate their skills and knowledge. They emphasized on the "mental challenge" and non-repetitive elements of their work. They also valued creative work, expertise, continuous learning, and the absence of monotony. This demonstrated that operators find satisfaction in showcasing their skills and using them to solve problems effectively.

On the other hand, operators explained that several aspects of the working environment were challenging. These challenges included noise, difficulty in concentrating, communication issues regarding the purpose of specific tasks, incomplete information, traceability problems during shift changes, and the physical demands of the job, such as numbness and pain of the hand, due to substantial pressure during sanding. Operators suggested that using more sophisticated tools, such as electric tools, could improve the physical aspects of the job.

During the discussion and design of the future process, operators emphasized concerns about safety working close to robots (Fig. 1(a)).

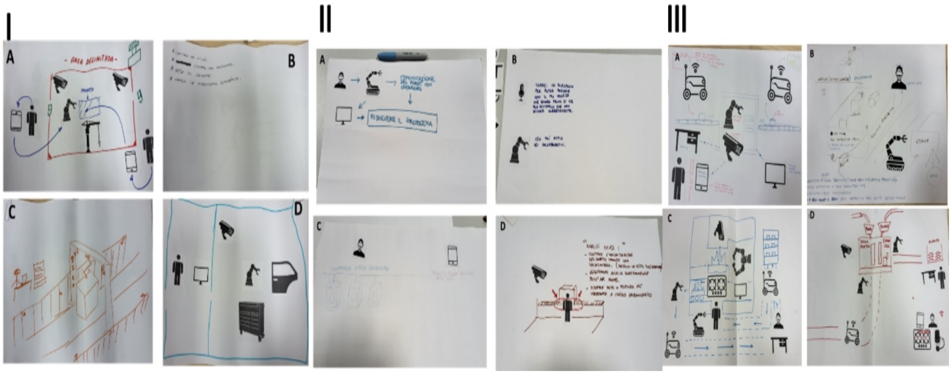

Figure 1: (a) Automotive industry; (b) white goods assembly; (c) additive manufacturing.

Operators labelled A, C, and D, in Figure 1(a), included barriers around the robot working area in their designs. Discussion revealed that initially, operators would consider light or conventional barriers, but with collaborative robots, the area surrounding the robot should be indicated by projection to prevent human entry. All four operators preferred engaging in complex task planning outside the main working area, leaving the repetitive aspects to the robot. Operator B suggested the need for automatic tool changes for the robot in addition to computer-controlled operations and camera vision.

White Goods Assembly

In this workshop, participants expressed that they are familiar with collaborative robots since they had either directly worked on processes involving collaborative robots or had managed the production lines that used them. Regarding the pleasant aspects and challenges of the work, participants who worked directly with a collaborative robot before, indicated that "the enjoyable aspect is learning something [when being trained to work with collaborative robot] and the removal of physical strain on the wrists and elbows". The other participants who managed the lines and operators, indicated that workstations with robotic technology require more work from the managing perspective: "robot can help with physical aspects, however, I still need to select the operators with the right characteristics and are more patient to learn". Overall, participants indicated that the most enjoyable aspects are learning new processes, new technology, and assigning operators to manual tasks that match their skills and abilities. While asked to design the future process, operators indicated variety of smart technology provided in Fig. 1 (b).

The main concern the operators had with the CONVERGING solution was the close proximity in which the collaborative robot and operator were working. Their issue with this aspect was that it would not be allowed in their factory. Other participants concurred, stating that there is limited application of the solutions due to factory regulations. Another concern raised was the possibility of the operator obstructing the robot due to close proximity: "Operator might accidentally block the sensors while moving their arms, and then robot slows down due to thinking that the operator is in the red area and the whole workstation will decrease in efficiency". Overall, participants agreed that collaborative robots and technology are useful but requires robust measures to ensure the distance sensors are not obstructed. In the discussion about the communication modes between operator and robot, participants indicated that having task instructions is a good way to help novice operators to gain confidence, although the "precise task sequence is known to all the operators". One of the participants indicated that even when operators know the steps of the process, "too much confidence can lead to errors", so a reminder of the correct procedures that's always visible to them would be helpful. Furthermore, participants preferred using voice interface where possible and having their hands free for the assembly. This indicated that smart watch controls as proposed 'in the CONVERGING solution, could interfere with the process. One of the participants suggested that having a touch screen instead of smart watch might be an option, as a screen is bigger and easier to view than a smartwatch.

Additive Manufacturing

The discussion with the participants about challenging and enjoyable aspects of the additive manufacturing indicated that the enjoyable aspects come from designing new ways to produce different components and working with metals conventional manufacturing cannot work with. On the other hand, participants indicated that "machines need to be more user friendly" and "the removal of the supports" is complicated and could be simplified. Furthermore, the removal of powder and putting the safety equipment are found uncomfortable. One of the operators indicated that from his experience "operators of additive manufacturing need to have more skills, and training is more difficult". Although formal training can take one week, "the training carries on inside – tutoring, shadowing more experienced operators, learning by doing".

When asked to design the process after discussing CONVERGING solution, operators indicated that an additional collaborative robot might be needed to further assist with the powder loading/removing process to completely remove the operator from this task. Operators also considered that interaction with the robot at their facility could take place with voice controls. However, they would prefer communication through gestures as that is similar to human-human interaction. While discussing with the participants how comfortable they would be working in a workstation which incorporated proposed technology, one of the participants indicated that they would be "at the beginning, careful" and another participant indicated that people would lose jobs ("one operator per two or three machines"), which would make them weary. Furthermore, another participant indicated that training would be essential – "knowledge how to handle robotic assistance would be very important, and operator training should include not only taking care of the machine but being aware of all the automation".

Aerospace Inspection

The workshop began with asking the operators about the challenges they face in the current process of fuel tank inspection and maintenance. The three primary issues raised were limited space and low visibility within the fuel tank, the time-consuming process of preparing the fuel tank prior to entering it, and the safety risks of the working in a fuel tank. These three points emerged as the main causes of multiple further problems faced by the operators while performing the current process.

The operators were encouraged to discuss their vision for using smart technology to improve their occupational challenges. There was a consensus that a machine should enter the tank instead of the operator, and visually capture the tank's internal environment. In this scenario, the operators suggested that they should be enabled to remotely view the images or visual feed of tank's internal environment sent by the machine. The operators stressed on the importance of the images and video having high-resolution, to ensure that the images or video captured by the machine shows all defects or foreign object debris inside the tank.

However, when asked about their opinions on the machine being a smart machine that can identify and notify the operator of areas of concern in the tank, the operators were divided in opinion. Some operators stated that it would be useful to have a machine that pointed out areas that needed work, although, they would only trust the machine if they were absolutely certain of its accuracy. Other operators seemed less trustworthy and stated that regardless of the machine, an operator would have to enter the tank to double check the inspection and carry out maintenance. The main concern that operators pointed out with the CONVERGING solutions was that even with a smart machine carrying out inspection, a human operator would have to sign off on task-completion paperwork. Therefore, while the machine would be acceptable for visual inspection, tasks such as sealant application, tightening components, and wiring can only be carried out by the operator.

DISCUSSION

The four workshops in different industries revealed that although the challenges and needs are industry and process dependent, there are several common aspects from new technology introduction which needs to be considered. These include trust in the technology, including its reliability and operator experience/knowledge; safety areas being clearly defined, separation between robot and human until the operator is confident; and anxieties about changing job roles and the impact on employment.

The findings from the workshop have two functions. Firstly, the ideas and further needs for the future processes were communicated by the operators which will be communicated to the process and robot developers. Secondly, the operators could express their worries and anxieties about the project's proposed solutions, which provides an understanding of future needs of operator engagement and how these anxieties can be reduced.

These main overlapping ideas are consistent with past research indicating that trust is related to the experience building and robot performance reliability (Hancock et al., 2011). Consistent performance, even though not 100% error proof encourages trust development and engagement with autonomous technology (Schaefer, 2016). Furthermore, changing employment sector and job roles are hot topics when discussing robotics, artificial intelligence, and smart tools. The unknown changes this technology will impact the job market causes anxiety (Erebak & Turgut, 2021) and might influence lack of acceptance even with clear benefits to the working environment (de Graaf et al., 2017). Finally, safety and physical comfort are the underlying aspects of manufacturing processes. Operators who experienced conventional robots which were separated from them by gates and light barriers could experience a massive change in work patterns and mental models (Adriaensen et al., 2022) if they have to directly interact with the robots.

By capturing these operators' anxieties about the future changes in technology and job roles, the project aims to use this feedback to ensure optimal trust, safety, and operator wellbeing in the implementation of the new smart productions system.

LIMITATIONS AND FUTURE DIRECTIONS

The findings so far are consistent with the past literature indicating that workshops encourage the development and expression of new ideas (Kristensson et al., 2008). However, the limitation from these workshops points the researchers towards the need to deliver the workshops earlier in the project and technology development, to capture feedback at an earlier stage. Furthermore, greater considerations towards the online method and company IT security measures are needed prior to delivering the workshop online (the online workshop was supposed to deliver the design activity with

Miro boards; however, it was not possible due to the company's IT security protocols). Future directions for the project involve reiterations of the workshops with prototypes of the robots and new technology.

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