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Integrating Human-Centred Design in AI-based Automation in Manufacturing: Ethical challenges and findings from Participatory Design Operator Workshops

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Abstract. Understanding human needs and the ways that workplace design can effectively address these needs is fundamental for improving the productivity and sustainability of a workforce. As automation increasingly replaces manual tasks in advanced manufacturing, it is crucial that human factors are considered throughout the stages of design and implementation. Initiatives like the EU AI-PRISM project aim to integrate human-centred design into new AI-based automation solutions to foster effective collaboration between humans and robots in challenging automated environments. AI-PRISM seeks to enhance productivity by combining advanced technology with human skills. To ensure that these automated solutions also meet the needs of their human operators and adhere to ethical standards, it is essential to incorporate human-centred design throughout both the design and implementation phases. The study described in this paper aims to identify the task-related challenges faced by current operators—from novices to experts—in four of the project's use cases in manufacturing companies. To achieve this, four participatory design workshops were conducted to gather valuable feedback on the planned AI-PRISM automation solutions and capture operator requirements across different manufacturing sectors: wooden furniture, photonics and microelectronics, white goods and brewery. The workshops incorporated group interviews, lasting about one hour each, that provided a platform for operators to share their experiences, concerns, and suggestions regarding the integration of AI and robotics into their daily tasks. The results revealed that operators across all groups faced challenges with fault detection, precision, and repetitive tasks. Responses also included a number of recommendations for the design of AI-based automation to address these challenges including enhanced interaction interfaces, human oversight for precision tasks and robotic assistance. In conclusion, the findings from this research highlight the importance of aligning human skills with automated technologies, which can lead to a more efficient and effective future for manufacturing.

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Keywords: Human-centred design, Participatory design, Human-robot collaboration, Manufacturing automation, Manufacturing AI, Operator feedback, Manufacturing efficiency.

1 Introduction

With increasing automation and artificial intelligence (AI) in modern production industries, the direct interaction between humans and automation can become both a key advantage and a major challenge for collaborative systems [3]. Where AI-driven automation increasingly replaces manual tasks, it is essential to ensure that human factors are prioritized throughout the design and implementation process. A human-centred approach not only enhances collaboration between humans and robots but also ensures that technology serves as an enabler rather than a barrier to efficiency and job satisfaction [8].

The EU AI-PRISM project is an initiative aimed at integrating human-centred design principles into AI-based automation solutions. However, for these solutions to be effective, they must be informed by the experiences, needs, and concerns of the workforce that will use them. While AI-based automation has the potential to improve efficiency and reduce operational costs in manufacturing, its successful implementation depends on how well it aligns with human operators' capabilities, skills, needs and ethical challenges [10]. A lack of human-centred design can lead to systems that are difficult to use, introduce new inefficiencies, or even reduce worker satisfaction. To solve this there is a need to ensure that AI-systems are aligned with human needs. This includes prioritizing key aspects such as explainability, transparency, and data privacy [6].

Current research on AI-driven automation often focuses on technological advancements without fully considering the challenges operators face in real-world settings. There is still a lack of extensive research on the social aspects of industrial robots, particularly in relation to the psychological factors in the manufacturing sector [1,2,9]. The current study aims to bridge this gap by identifying the task-related difficulties and ethical challenges that manufacturing operators encounter and providing insights into how AI-based automation can be designed to better support their work. To achieve the aims of the study, several key objectives were outlined. First, the study sought to identify the task-related challenges faced by operators across four distinct manufacturing sectors. This was followed by the collection of valuable operator feedback on existing automation solutions and ethical concerns through participatory design workshops. The study then analysed the common themes and challenges that emerged, particularly those related to fault detection, precision, and repetitive tasks. Based on these insights, human-centred design recommendations were proposed to improve AI-based automation, with a focus on enhancing usability, collaboration, and efficiency. Finally, the study aimed to contribute to the development of AI-PRISM solutions by ensuring that automation technologies were better aligned with the needs of human operators.

2 Methodology

2.1 Procedure

This study employed a qualitative research methodology through participatory workshops conducted in four use cases (Silverline (white goods), Athenian Brewery (brewery), Andreu World (wooden furniture) and Vigo (photonics/ microelectronics)) and in two stages. In stage one, participants were asked questions to assess their current work processes, decision-making, and challenges. Discussions focused on task variations, error correction, difficulties faced by new operators, desired improvements, job satisfaction, and preferred training methods. In stage two, participants engaged in a hands-on design task, using a workstation layout to map operator positions, technological support needs, and potential improvements. They were introduced to pre-identified automation solutions and engaged in discussions on robotic applications. The session concluded with a roundtable discussion between operators and moderators, ensuring that insights directly informed human-centred AI-based automation solutions.

2.2 Participants

Participants were recruited by the use case leaders asking for volunteers for the project data collection. Prior to data collection, participants were explained aims of the project, process of data collection and data usage, participants rights and potential harms and benefits of the procedure. The use case leaders were assisting the communication between the user and the researcher by translating to the participants native language and English. Only participants gender and experience level were recorded for the initial data collection (Table 1).

Table 1. Operator Demographics by Use Case

Use Case	Total Participants	Gender (F/M)	Experience Level (Novice/Experienced) [1]
Wooden Furniture	10	1F / 9M	8 Novices (1F) / 2 Experienced
Photonics/ microelectronics	5	1F/4M	4 Novices (1F)/1 Experienced
White goods	4	1F/3M	2 Novices/ 2 Experienced (1F)
Brewery	6	1F/5M	1 Novice/ 5 Experienced (1F)

[1]Expereince level: 0-5 years for novice and 6+ years for experienced (Mehta et al., 2018).

2.3 Ethical considerations

This research was approved by the Cranfield University Research Ethics Committee, and conducted in accordance with the Cranfield Research Integrity Policy, the British Psychological Society's Code of Human Research Ethics, and the General Data Protection Regulation 2018.

2.4 Data analysis

The qualitative data collected from the interviews and observations were analysed using thematic analysis. This approach involves identifying and analysing patterns or themes within the data (Lochmiller, 2021), which can reveal the core challenges operators face when interacting with AI-based automation. The analysis focused on recurring issues related to fault detection, precision, and the repetitive nature of certain tasks, as well as operators' concerns regarding the human-robot interface and their recommendations for improving usability. By categorizing and coding the data, the study identifies key insights into how AI-based automation systems can be better aligned with human needs and skills.

3 Results

The participatory design operator workshops revealed several key ethical challenges and technological needs across various industrial settings. The findings highlighted the complexities of human-robot collaboration, the necessity of improving workplace conditions, and the ethical considerations in automation. During the wooden furniture use case workshop, participants highlighted several painting challenges, including difficulties with vertical colour application, insufficient cabin lighting, frequent equipment cleaning between material changes, precise colour matching, and maintaining the correct pressure and spraying distance. Operators also faced quality defects and difficulties in handling heavy materials. In the sanding process, issues such as learning techniques, performing double sanding, inadequate lighting, and the necessity of reworking chairs were presented. Proposed technological improvements include robots to assist with mixing materials, applying paint, and supporting weight and positioning. For sanding, improvements in aspiration systems, reduced suction holder diameters, robotic sanding assistance, and VR glasses for defect detection were recommended. The ethical challenge remained in balancing automation with operator job security and ensuring safe human-robot interaction.

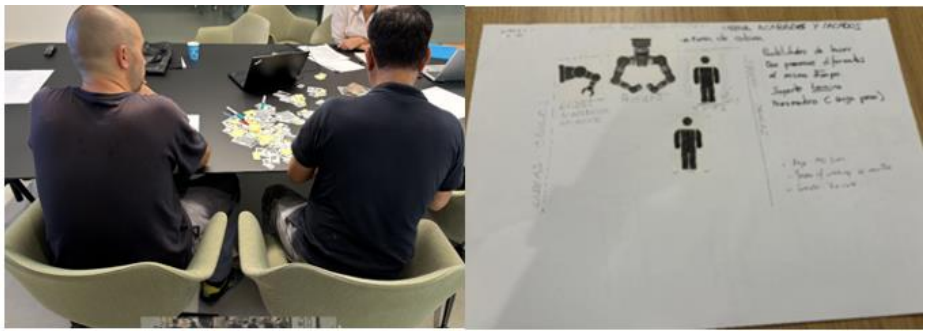

Fig. 1. The wooden furniture use case participatory workshop (photo by the author)

During the photonics and microelectronics use case workshop, operators identified several high-precision tasks that demanded significant time and effort, such as microscope calibration, precise glue application, and achieving a uniform wax layer on plates. A significant issue was the potential bending of wire tips, which could compromise product integrity. Participants suggested automating positioning and calibration using robotics, with human confirmation for accuracy. They also proposed data-sharing between machines to ensure consistency and detect errors, remote process control for enhanced efficiency, and AI-assisted calibration to improve precision. However, ethical concerns raised regarding the reduction of operator routines, potential skill loss, and the necessity of maintaining human oversight to prevent automation errors.

Fig. 2. The photonics and microelectronics use case participatory workshop (photo by the author)

During the white goods use case workshop, participants highlighted several key challenges, including difficulty detecting faults through visual and tactile inspection, physical strain from handling large components, repetitive barcode application, and mental fatigue from prolonged tasks. Repetition-induced fatigue poses a risk to both efficiency and operator well-being. AI-driven vision control for error detection, robotic testing for electrical and ground faults, and automated packaging were identified as key solutions. However, challenges such as reduced social interaction, operator isolation, and ethical concerns about over-reliance on automation were noted. To address these

concerns, maintaining operator decision-making authority through voice and touch-screen interfaces was emphasized as a critical safeguard.

Fig. 3. The white goods use case participatory workshop (photo by the author)

Finally, the brewery use case workshop highlighted several significant challenges faced by operators, including the physical demands of manual handling and repetitive tasks, time-consuming processes, and the risk of errors in material selection. Additionally, the lack of real-time monitoring made it difficult to track operations effectively, while the absence of standardized procedures in certain areas further complicated workflow consistency. To address these challenges, automation solutions were proposed, such as robots equipped with adaptive error-detection capabilities to minimize mistakes, real-time monitoring systems using sensors to enhance operational oversight, and improved human-machine interaction to create a safer working environment. From an ethical standpoint, the workshop emphasized the need for comprehensive training programs to prevent skill degradation as automation increases. There was also concern about maintaining worker engagement in an environment that is becoming more automated, ensuring that employees remain motivated and valued despite the shift in tasks and responsibilities.

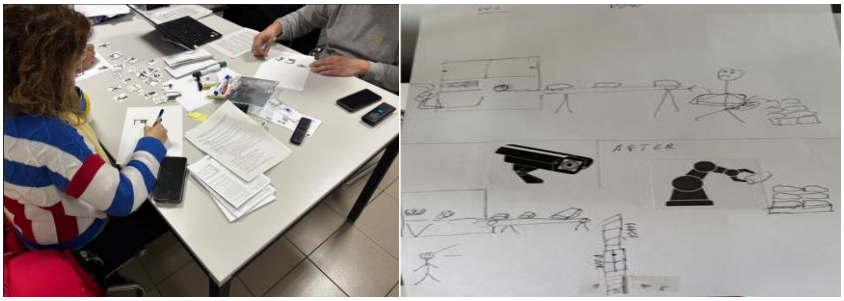

Fig. 4. The brewery use case participatory workshop (photo by the author)

4 Discussion

Findings of this paper provided great information into the challenges operators face with AI-driven automation across various manufacturing sectors. A common theme emerged around the complexities of human-robot collaboration, where operators faced task-related difficulties in precision tasks such as colour matching, fault detection, and material handling. While automation offers potential to reduce manual effort and enhance efficiency, operators raised concerns about losing control and job satisfaction, particularly in tasks that require skill and precision. Schwabe and Castellacci [7] also found that in recent years, automation in industrial firms has led 40% of currently employed workers to worry that their jobs could eventually be taken over by smart machines. This concern alone, however, does not justify operator involvement; rather, their role is essential for ensuring accountability, flexibility in complex scenarios, and the application of experiential knowledge that current AI systems may not fully replicate. Maintaining operator oversight supports real-time adaptation, safeguards quality, and fosters user trust in automated processes, which is crucial for successful technology adoption.

It is vital that operators maintain some level of oversight and decision-making authority, even in increasingly automated environments. Task-related challenges were prevalent across all sectors. In the white goods industry, operators struggled with fault detection and physical strain, pointing to AI vision systems and robotic testing as promising solutions. Similarly, the brewery sector faced difficulties with time-consuming tasks and lack of real-time monitoring, proposing the use of sensors and robots with adaptive error detection. These solutions could greatly improve efficiency but must be designed in a way that maintains human involvement and avoids total replacement of operators. In photonics and microelectronics, tasks such as microscope calibration and glue application demanded high precision, with operators suggesting human confirmation in automation processes to ensure quality control. Ethical considerations were also a major concern. Operators in all sectors expressed fears about skill degradation due to automation, as well as the psychological effects of isolation and reduced social interaction. Several participants mentioned that automation sometimes reduces opportunities for collaboration, peer learning, and Interpersonal connection at work that contribute significantly to workplace satisfaction and mental well-being. Addressing these social dynamics is crucial, as prolonged operator isolation may lead to reduced motivation and engagement over time.

Ensuring robust training programs and maintaining human engagement in decision-making were emphasized as key ethical safeguards. This helps to balance automation with human involvement and preserve both job satisfaction and operational efficiency among users. Overall, the workshops highlighted the need for AI-based automation systems that are not only technologically advanced but also human-centred, fostering collaboration, transparency, and ethical practices to enhance both productivity and worker well-being in manufacturing environments.

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