

Design Your Cobot, Shape Your Workplace: Insights From a Participatory Design Session

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Abstract

Industry 5.0 highlights the importance of integrating human needs and values into the design of human-robot workspaces, especially for collaborative robots that work in close proximity with humans. However, there is still little guidance on how to involve employees with different roles as co-designers when (re)designing cobot-avatar workstations in real industrial settings. To explore how such involvements can be realized, this paper presents a participatory design session for cobot-avatar workstations and reports insights from its evaluation with three employees of a manufacturing company, who created pen-and-paper prototypes during the session. The qualitative analysis of these prototypes and the accompanying discussions reveals shared and role-specific requirements for safety, ergonomics, and the division of responsibilities between cobots, avatars, and workers in everyday production. Based on these insights, we provide implications for human-centered cobot-avatar workstations and discuss the value of participatory design as a method for aligning Industry 5.0 principles with practical workspace design.

CCS Concepts

- **Human-centered computing** → **HCI design and evaluation methods; Participatory design; Interface design prototyping;**
- **Applied computing** → *Industry and manufacturing.*

Keywords

Human-Centered AI, Co-Creation, Human-Robot Interaction

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1 Introduction

Since its emergence around 2020, the concept of Industry 5.0 describes the transition toward manufacturing systems that prioritize human needs, capabilities, and values [1, 21, 22, 30]. In contrast to earlier industrial transformations that largely centered on automation and the substitution of human labor, this new paradigm highlights the importance of meaningful human-robot collaboration. Rather than positioning robots as autonomous replacements of workers, Industry 5.0 envisions collaborative robots (cobots) as partners that operate in close physical proximity to human workers, engaging jointly in shared tasks [11, 15, 31]. Such collaboration is not solely a technological challenge but also depends on workers' experiences, expectations, and the working processes that shape their interaction with robotic systems. Therefore, effective collaboration requires careful consideration of human factors, ergonomics, and workspace design [2, 9, 23].

Existing research on human-robot collaboration in industrial and manufacturing settings has examined ergonomic workstation design, worker acceptance, and the configuration of collaborative robot workcells, often through lab-based studies or early-stage prototypes. However, much of this work either focuses on concept development before robots are deployed, engages only single stakeholder groups (e.g., operators or engineers), or considers collaborative robots without additional digital companions such as avatars. There is comparatively less research on participatory design processes in companies where cobots are already integrated into everyday production and where multiple roles jointly envision future cobot-avatar workstations for Industry 5.0 contexts. Our work contributes to this space by adapting participatory design methods to such a setting and deriving context-specific implications for cobot-avatar workstation design.

In our earlier work [12], we examined how employees from a manufacturing company engage with an actual cobot in combination with an avatar. Our findings emphasized the importance of personalized communication and task assistance.

Building on these insights, the present study shifts the perspective from observing interaction with an existing system to exploring how workers themselves envision desirable human-cobot interaction. To this end, we conducted a one-hour design session in which three employees of a manufacturing company created pen-and-paper prototypes of their ideal future cobot-avatar workstation

using a variety of craft materials. This approach not only identifies practical, workplace-related knowledge that may remain unspoken in interviews, but also empowers employees to articulate preferences, constraints, and creative ideas that are grounded in their everyday work realities.

By situating employees as co-designers rather than passive end-users, our design session reveals how they imagine roles, spatial configurations, and modes of cooperation with a cobot. The resulting pen-and-paper prototypes offer valuable insights for designing cobot-avatar workspaces that align with the needs of those who will work with them.

2 Related Work

2.1 Human-Robot Collaboration in Industry

Worker safety has always been a primary concern when integrating cobots into industrial settings [10, 20]. Initially, robots were physically separated from workers by barriers to ensure safety. With Industry 5.0, there has been a shift towards close human-robot collaboration, requiring safe robot behavior. For example, modern cobots are designed with collision-avoidance strategies that minimize physical harm to workers. These strategies not only protect workers but also build trust in cobot technology, which, in turn, supports its broader acceptance and adoption in the workplace. However, the human-centric nature of Industry 5.0 and successful adoption of cobots extends beyond physical safety [14, 29]. Deploying cobots in factories reduces traditional human-human interactions among workers, which may contribute to feelings of loneliness and a lack of social support, both of which are critical for mental well-being [8, 16].

Ideally, cobots could evolve to act as supportive colleagues, interacting socially with the workers [6, 13]. This expanded role implies that cobots should be equipped to perceive and respond to social cues from workers. For instance, a cobot that detects stress in a worker could adjust its behavior (e.g., by changing its movement speed or offering assistance). Previous studies have explored the effective adaptive behaviors of the cobot and the appropriate adaptation timings, such that these behaviors do not disrupt production cycles [13, 18]. More recently, studies have investigated the implementation of human-like features such as eyes/glasses and movements reflecting breathing rhythm, to express social cues [17, 25]. To this end, studies have also explored displaying expressive faces either as part of the robot (e.g., Baxter robot) or through tablets or displays [3, 4].

2.2 Participatory Design Approaches

By bringing cobots into real-world applications and environments, the need to involve stakeholders in the design process becomes increasingly important. Participatory and human-centered design approaches are applied to develop cobot setups for manufacturing contexts. Human-centered AI design highlights the importance of considering human stakeholders when developing AI-based systems [19]. This perspective emphasizes that stakeholders' abilities, needs, and perceptions must be reflected in the design process. User-centered methods are often combined with participatory design, in which stakeholders are actively involved in shaping a technological system [24]. Those approaches can redistribute power between

developers and users and often lead to better outcomes, such as smoother integration of new technologies into work processes [27]. Participatory methods enhance trust and understanding in users while also detecting challenges that developers may otherwise overlook [7]. Empirical studies demonstrate that integrating workers' knowledge through human-in-the-loop design results in more practical and acceptable cobot-supported workflows [5]. Vermeulen et al. [26], Weitz et al. [28] highlight that involving workers directly in the design of collaborative tasks not only improves safety and usability but also provide richer insights than quantitative approaches alone.

3 Methodology

3.1 Participants

For the workshop, we invited three participants from a German manufacturing company that already deploys cobots in its production line. The participants (two male, one female) represented different roles within the company – a cobot worker, a learning and development manager, and an ergonomics and health manager – providing perspectives from different stakeholder groups. All participants had prior experience interacting with cobots in their workplace but had not yet worked with an avatar-based companion system.

3.2 Concept

The 1.5-day workshop followed a three-phase structure: (1) an initial group discussion to establish rapport and understand participants' work contexts; (2) a prototype demonstration enabling hands-on interaction with a cobot-avatar prototype; and (3) a participatory design session to elicit feedback for prototype refinement and integration into the production line (see Figure 1). In this paper, we focus on the third phase— the participatory design session— while briefly outlining the other workshop phases to provide the necessary context.

Group discussion. On the first day, a combination of short talks and group discussions took place. The talks provided participants with an overview of the research project and introduced key topics relevant to the researchers (i.e., cobot failures and proactivity). For each topic, the researchers engaged in discussions with the stakeholders to learn about their perspectives and to understand whether and how these issues were addressed within their company.

Prototype demonstration. At the beginning of the second workshop day, all participants engaged with a scripted, industry-like cobot prototype that was augmented with a virtual character. During the interaction, the robot deliberately made errors, and the avatar communicated these errors to the participant. Following the interaction, participants provided feedback during a focus group interview. This approach provided valuable insights about the cobot, the avatar, ways to improve its behavior, and practical aspects of using the setup in industrial workplaces. Details about the setup and the interview can be found in [12].

Participatory Design Session. We developed a one-hour participatory design session to explore employees' requirements for integrating cobots and avatars into their company's manufacturing

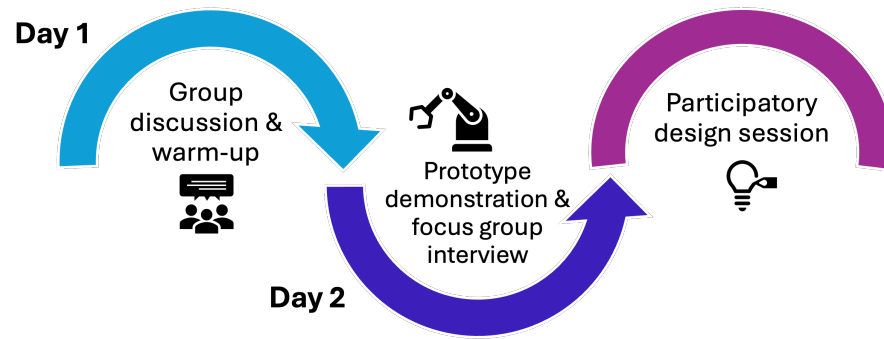


Figure 1: Overview of the 1.5-day workshop structure. This paper focuses on the final phase, the participatory design session (shown on the right).

workplaces. During this session, participants provided feedback on four topics: the cobot, the avatar, additional workplace requirements, and potential solutions to issues they noticed during the prototype demonstration (see Subfigure 2a). At the beginning of each topic, a short example was provided to illustrate the design task. Participants were then encouraged to get creative using a variety of materials, ranging from different types of pencils to images and icons. After the creative phase for each topic, participants presented their results during the discussion. To reduce hierarchical influence arising from different organizational roles during ideation, participants first designed their individual solutions for the four topics before presenting and discussing them collectively.

3.3 Analysis

For analysis, all designed pen-and-paper artifacts and discussion notes were systematically clustered and qualitatively coded by the first author. The results were then collaboratively reviewed with the co-authors in an iterative process to resolve disagreements and refine the analysis. Coding was guided by the four topics (i.e., robot & tools, avatar, additional requirements, and solutions for problems). All materials were reviewed in their original form before coding to ensure that interpretations remained grounded in the collected artifacts. The analysis was conducted in German, and all resulting codes, themes, and interpretations were translated into English by the first author for reporting. To stay close to the original pen-and-paper artifacts, English translations were added to Figure 2.

4 Insights & Design Implications

Drawing on the prototypes and discussions from our participatory design session (see Figure 2) with employees of a German manufacturing company that already operates cobots in pre-assembly and assembly but has not yet worked with avatars in this setting, the session revealed several key insights regarding the integration of cobots and avatars in industrial workspaces. The subsequent comparative analysis across stakeholders was along the introduced topics *cobot*, *avatar*, *additional requirements*, and *solutions for problems*. While participants emphasized several overlapping requirements for the cobot-avatar workstation, their prototypes nonetheless revealed role-specific emphases. In the following, we therefore

summarize first the role-specific insights before adding the shared findings and derive actionable design guidelines for cobot-avatar workstations in comparable Industry 5.0 contexts.

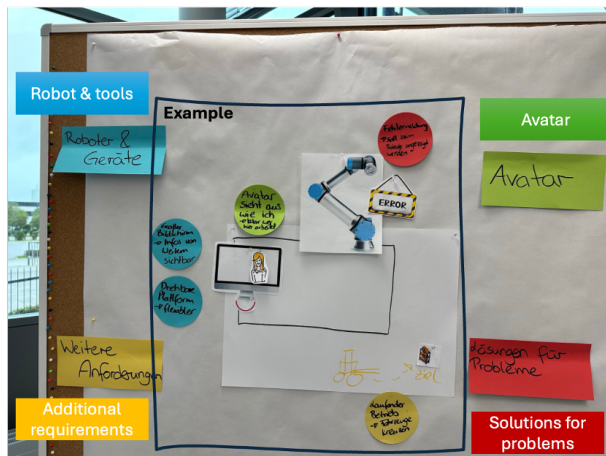
The **ergonomics and health manager** (see Figure 2b) primarily framed the workstation through the lens of physical well-being and safety. Their design highlighted a clearly defined ergonomic “hot zone”, height-adjustable furniture, and an orderly layout that minimizes unnecessary walking and awkward postures. In this view, the cobot mainly serves to reduce physical strain by handling repetitive or awkward subtasks, and the avatar is a restrained information channel that should not distract workers in a safety-critical environment.

The **learning and development manager’s** prototype, by contrast (see Figure 2c), integrated the avatar more strongly as a socio-informational interface that explains process steps, visualizes performance over time (e.g., output, cycle times, and errors), and relays selected company or production information. Here, cobot and avatar jointly form a didactic setting in which hands-on interaction with the cobot is accompanied by contextual explanations and feedback tailored to different experience levels.

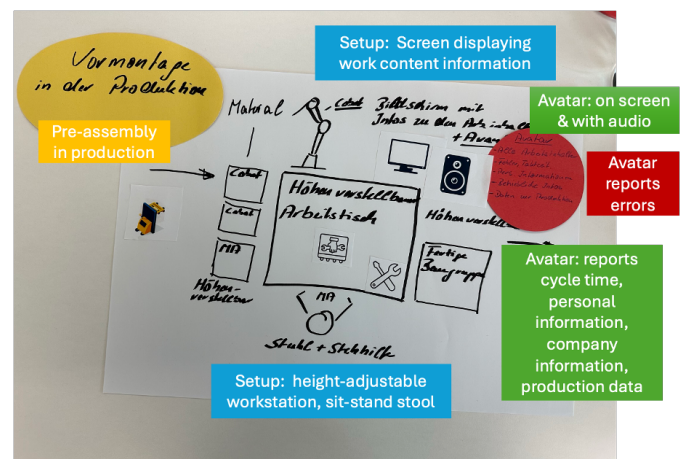
The **worker’s** prototype (see Figure 2d) focused most strongly on the practicalities of everyday production work. Their layout centered on keeping tools and materials within immediate reach, avoiding unnecessary movement and setup effort, and using the cobot to take over heavy, monotonous handling tasks while preserving human control over process flow and quality decisions. The avatar was envisioned as a useful companion that surfaces key production indicators and occasional motivational cues without overwhelming the worker. Personalizable elements such as a mobile trolley or dedicated storage underscored the importance of ownership and continuity at a shared cobot-avatar workstation.

Based on the insights, we derive the following design implications:

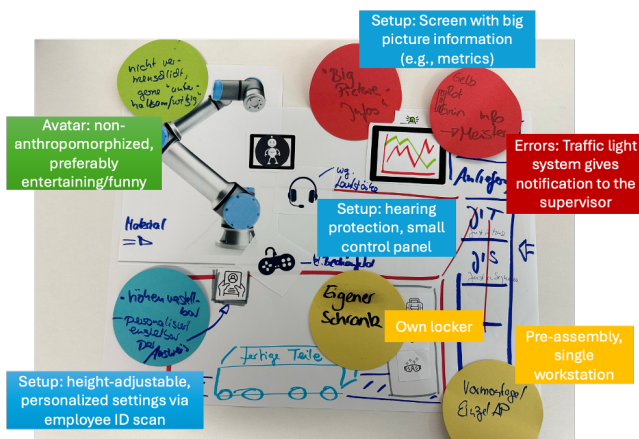
- (1) **Design the workplace around the worker in stationary, repetitive assembly contexts:** Across all three stakeholder roles, participants converged on the need for a workstation that is structured around the worker’s ergonomic comfort and control rather than around the robot. Concretely, this entails: (a) a modular, ergonomically adaptable setup (e.g., height-adjustable tables, rotatable displays), that can be



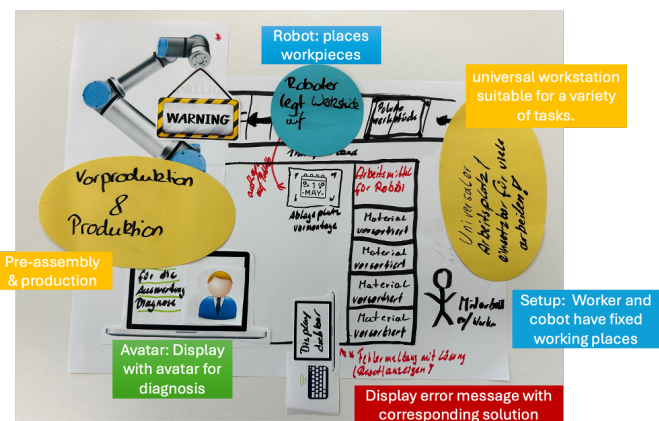
(a) The design session focused on four topics: (1) robot & tools, (2) avatar, (3) additional requirements, and (4) solution for problems.



(b) Pen-and-paper result of the ergonomics and health manager.



(c) Pen-and-paper result of the learning and development manager.



(d) Pen-and-paper result of the worker.

Figure 2: Overview of the pen-and-paper prototypes created by the three participants during the design session.

tuned to individual body height and handedness; (b) a clearly defined “hot zone” in which frequently used materials and tools remain within comfortable reach without unnecessary walking or stretching; and (c) personalizable storage (e.g., a mobile trolley or dedicated drawers) that gives workers a sense of ownership and continuity, even when the cobot is added or reconfigured. These implications are grounded in serial pre-assembly and assembly tasks where workers remain stationary at a cobot-equipped workstation.

- (2) **Integrate the cobot as work enhancer:** In the envisioned future workstation, the cobot is embedded as a supportive partner that takes over physically repetitive or ergonomically demanding subtasks (e.g., placing incoming workpieces, repositioning parts, removing finished items) while leaving process control, quality decisions, and exception handling with the human worker. Layout and reach planning should therefore treat the cobot’s motion as tightly coupled to the placement of materials and fixtures, so that the cobot brings

parts into the worker’s ergonomic zone rather than forcing workers to adapt to the robot. Error communication should follow a multimodal escalation pattern: the cobot first signals problems through embedded cues (e.g., lights, posture, brief motion pauses) and only then escalates to richer explanations via the avatar. This pattern assumes collaborative robot arms in fixed workstation configurations where the human remains the accountable process owner.

- (3) **Use the avatar as a socio-informational companion interface:** Participants envisioned the avatar not as a fully autonomous teammate, but as a situated interface that (a) reflects ongoing work activity (e.g., current output, cycle time, recent errors), (b) provides selected company and production information that fosters a sense of belonging, and (c) offers lightweight motivational feedback aligned with the rhythm of work. The avatar should be accessible via a local display at the workstation and support limited personalization, such as the level of detail shown, the temporal granularity of

feedback (e.g., shift vs. daily view), and a preferred communication tone (e.g., neutral vs. slightly humorous characteristics). At the same time, its behavior must remain predictable and unobtrusive in a safety-critical industrial environment, avoiding continuous chatter or intrusive animations that could distract from the task. These implications specifically target cobot workstations where the avatar complements, rather than replaces, direct interaction with the robot and physical workspace.

Taken together, this operationalizes a human-centered, resilient, and supportive form of automation that aligns closely with the ambitions of Industry 5.0 [1, 21, 22, 30] and related work on human-centered manufacturing and collaborative robotics [14, 29].

At the same time, while the worker and management perspectives contributes to a broader understanding of requirements for effective HRI in industrial workplaces, this also constitutes a limitation: the workshop involved only three participants, all from the same company. Notably, two of the three participants hold management roles, which may have influenced the discussion toward organizational perspectives rather than everyday worker concerns. The worker's prototype focused on tool access and process control, topics that were less central in the management designs. Future studies should include a more balanced mix of roles to better account for power dynamics. However, this narrow sample comes with a clear advantage in ecological validity: participants were not speculating about hypothetical scenarios, but drawing on direct experience from an organization that is already deploying cobots in a genuinely collaborative worker-cobot setting.

The participatory design session demonstrated the value of involving employees as co-designers to develop human-centered cobot-avatar workstations. The design session built on two sources of experience: participants' existing work experience with cobots in their company and their interaction with the cobot-avatar demonstrator in the preceding workshop phase (see [12] for details). In this demonstrator phase, they encountered issues they later addressed in the design session (e.g., a more personalized avatar) and generated ideas for additional functionalities (e.g., providing production updates). Therefore, we recommend that participatory design sessions are not conducted in isolation, but are combined by hands-on exploration of the envisioned setup. This combination allows participants to interact directly with the specific system under design, which helps uncover real-world requirements and challenges that might not emerge in abstract discussions alone.

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