

# Appendix: From System to Teammate: Human-Centered AI in the Industrial Internet of Things

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**Table 1.** First-order themes, second-order themes and aggregate dimensions (TTF)

|                      | 1st-order theme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2nd-order theme | Aggregate Dimensions        |
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| Task characteristics | <ul style="list-style-type: none"><li>• It must be possible to respond to emergencies, especially in safety-critical tasks that require human oversight [1, 2].</li><li>• Transparency and understandable explanations of AI decisions are required so users know how algorithms work and why decisions are made [2–4].</li><li>• Explanations should be effective and delivered in a way that considers the user’s cognitive load and timing [5].</li><li>• Increased cognitive or physical workload can lead to fatigue, injuries, and poorer decision-making, especially in highly automated environments [6, 7].</li><li>• User feedback and interaction with AI should not create additional burden for employees [5].</li><li>• People should maintain autonomy in their tasks and be supported in improving human factors such as emotions and well-being [5, 8].</li><li>• AI can analyze tasks with respect to well-being in order to improve them [5].</li><li>• Domain knowledge must be continuously updated, while recognizing that implicit employee knowledge is difficult to formalize for AI systems [9].</li><li>• The best answers to questions may change over time and therefore require continuous updating [1].</li></ul> | Human factors   | HCAI is not a silver bullet |

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| Technology characteristics | <ul style="list-style-type: none"> <li>• AI systems and underlying technologies must be regularly updated and maintained to remain effective in changing environments [1, 2].</li> <li>• AI should be able to handle poorly formulated inputs, but current systems still struggle with context understanding and reasoning [1, 2].</li> <li>• Many powerful AI models (e.g., deep neural networks, LLMs) function as black boxes, which limits transparency, interpretability, and adaptability [3, 4, 8, 10].</li> <li>• AI systems can produce biased, unpredictable, or hallucinated outputs; careful data collection, processing, and techniques such as Retrieval-Augmented Generation or simulation can help mitigate these issues [3, 5, 9–12].</li> <li>• Integrating human-centered AI into existing legacy infrastructures remains technically complex and costly [2].</li> <li>• AI systems require access to appropriate knowledge bases, since they can only perform tasks for which relevant knowledge has been made available [9].</li> <li>• Technology does not automatically account for ethical implications, so ethical guidelines must be explicitly considered and implemented [2, 11, 12].</li> <li>• Designing AI that is adaptive, customizable, and capable of understanding human behavior and socio-cultural aspects (e.g., emotions) remains technically challenging [2, 5].</li> </ul>                                                                                                                                                                                                                                          | <b>Trans-<br/>parency<br/>&amp;<br/>explaina-<br/>bility</b> |  |
| Task-technology fit        | <ul style="list-style-type: none"> <li>• LLMs may produce superficial answers that are insufficient for decision-making; therefore, transparency about their limitations and appropriate use cases is necessary [1].</li> </ul> <p>In high-risk scenarios, AI capabilities must be controllable, with a balance between high automation and strong human oversight [1, 5].</p> <ul style="list-style-type: none"> <li>• Transparency and explainability are essential so that users can understand AI outputs and make informed decisions based on them [3, 12].</li> <li>• AI systems should incorporate human limitations, preferences, goals, and emotions, while also helping users understand the AI's reasoning [2, 11].</li> </ul> <p>Systems should remain flexible and adaptable to changing user needs and avoid rigid protocols that restrict human decision-making [2, 8].</p> <ul style="list-style-type: none"> <li>• User feedback and user data are important for improving AI systems; however, the roles and expertise of users must be considered when evaluating feedback [5, 7].</li> <li>• Factors such as trust, engagement, security, explainability, and usability must be considered to achieve an effective human-AI collaboration [6].</li> <li>• Adaptive interaction mechanisms (e.g., adjusting explanations based on cognitive load detected through methods like eye tracking) can improve usability [2].</li> <li>• AI learning can be supported through expert knowledge sharing, intelligent questioning strategies, and training approaches such as reinforcement learning in simulated environments [9, 12].</li> </ul> | <b>Tech-<br/>nical<br/>capabili-<br/>ties</b>                |  |

**Table 2.** First-order themes, second-order themes and aggregate dimensions (SPT)

|                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                           |
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| <b>Perceived Social Presence</b> | <ul style="list-style-type: none"> <li>• AI explanations should be carefully designed in terms of format (e.g., text, visuals, speech) and timing to ensure effective communication with users [5].</li> <li>• Interaction methods should be natural, direct, and personalized to support intuitive human-AI communication [5, 7].</li> <li>• Designing systems that are immediately usable in different environments is challenging, as context constraints (e.g., noise or unavailable devices) can limit certain interaction methods [9].</li> <li>• Customization and adaptive behavior through machine learning can empower users and allow AI systems to adjust to individual needs [3].</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Interaction design</b>     | <b>HCAI as a Teammate</b> |
| <b>Social Cues</b>               | <ul style="list-style-type: none"> <li>• AI systems should communicate their learning status and progress transparently to users, for example through visual indicators [5].</li> <li>• AI should act as a collaborative partner rather than just a passive tool, adapting transparency and interaction based on how users perceive its capabilities [2].</li> <li>• The framing and naming of AI technologies influence user expectations and how the system is perceived [9].</li> <li>• Natural language communication through conversational interfaces is important for interaction, but can be challenging when handling complex operational data [7].</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Personalization</b>        |                           |
| <b>Interactivity</b>             | <ul style="list-style-type: none"> <li>• Interaction with AI should use familiar and accessible communication channels (e.g., smartphone apps or messaging platforms) and support natural language communication [1, 2, 9].</li> <li>• AI-human interaction should enable a seamless, bidirectional exchange of information, allowing users not only to receive information but also to negotiate decisions and provide input to the system [2, 5, 9].</li> <li>• Interaction design must support continuous, proactive, and carefully planned communication between humans and AI [5, 13].</li> <li>• AI systems should be integrated into team contexts, enabling evaluation and support of both individual and team performance [5].</li> <li>• Interfaces and interaction should be adaptable and personalizable, including adjustments based on users' cognitive load [7, 8].</li> <li>• Conversational interfaces are often suitable for first-level support but cannot fully replace human assistance in more complex situations [12].</li> <li>• Security risks such as prompt injection can influence interactions and negatively affect users' trust in the AI [2].</li> </ul> | <b>Human-AI collaboration</b> |                           |

**Table 3.** First-order themes, second-order themes and aggregate dimensions (PAT)

|                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                |                                  |
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| <b>Responsibility</b>        | <ul style="list-style-type: none"> <li>•When using external LLM services, users must avoid sharing confidential company information, as they may unintentionally represent their employer to the provider [1].</li> <li>•Responsibilities and accountability for AI decisions and outputs must be clearly defined, especially in cases where the AI fails or supports high-stakes decisions [2, 8, 10].</li> <li>•Transparency and explainable AI (XAI) are necessary so that users can understand AI outputs, justify decisions, and take responsibility [2, 5].</li> <li>•AI systems should understand employees' roles and responsibilities in order to provide appropriate information and support decision-making [5].</li> <li>•Automation bias should be identified and mitigated so users remain critical of AI recommendations [2].</li> <li>•Technical solutions such as blockchain can help ensure traceability of decision-making processes [2].</li> <li>•Organizational factors influence AI use: employees may withhold knowledge to maintain power, and responsibilities may need to be dynamically reassigned (e.g., through ticket systems) while encouraging effective knowledge sharing [9].</li> </ul> | <b>Accountability</b>          | <b>Responsible AI governance</b> |
| <b>Information Asymmetry</b> | <ul style="list-style-type: none"> <li>• Training materials and prompts used within the company should be transparent and accessible internally [1].</li> <li>• The use of user data requires informed consent, secure handling (e.g., encryption and restricted access), and transparent privacy policies [3].</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Organizational adoption</b> |                                  |

|                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |  |
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| Alignment of Interest | <ul style="list-style-type: none"> <li>• Bias, misinformation, and over-reliance on AI can lead to decisions that conflict with organizational goals; therefore, bias must be regularly monitored and addressed [1, 8].</li> <li>• Bias in data can be leveraged for innovation or competitive advantage [11].</li> <li>• Organizations are responsible for monitoring AI systems to ensure safety, ethical compliance, and alignment with human values and needs [2, 10, 13].</li> <li>• Ethical principles, laws, and standards are required to guide the responsible use of AI and enable developments such as Industry 5.0 [12, 13].</li> <li>• Companies must balance innovation, productivity, and performance with employee well-being and broader social and environmental responsibilities [2, 8, 10, 13].</li> <li>• Regular training and continuous skill development are necessary so employees can interact with AI systems as intended [5, 13].</li> <li>• Employee interaction and feedback (e.g., correcting or rejecting AI decisions, labeling data, or providing well-being feedback) can help improve systems and working conditions [5].</li> <li>• Transparency is important regarding AI's impact on employees, including job security, data handling, and privacy protection [8, 9, 12].</li> <li>• Acceptance and accessibility must be considered: human-centered AI should have low barriers to entry in terms of cost, usability, and staff acceptance [4].</li> <li>• Knowledge management within organizations remains challenging, as employees may lack incentives to document knowledge, but mechanisms such as reviewed or annotated knowledge records can help capture expertise [9].</li> <li>• Isolated negative experiences with AI should not disproportionately shape long-term system usage and perception [9].</li> </ul> | Data privacy & security |  |
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| Trust | <ul style="list-style-type: none"> <li>• It must be transparent where data is stored (e.g., locally or externally) and strong security measures must be implemented to protect employee data [1, 2].</li> <li>• Organizations must ensure robust data governance, including privacy-compliant data acquisition and processing, user control over personal data, and protection against risks such as malicious third-party data in training datasets [8, 10].</li> <li>• Special care is required when handling sensitive employee data such as audio or video recordings, as well as technologies (e.g., mandatory smartphones) that could be perceived as monitoring [9].</li> <li>• Ethical principles and frameworks, supported by governance structures and design guidelines, are necessary to prevent misuse of AI by employers and ensure responsible implementation [2, 12].</li> <li>• Explainable AI (XAI) can help mediate between employers and employees by clarifying the organizational impact of AI-supported decisions [5].</li> <li>• The implementation of AI raises ethical concerns due to its real-world consequences for employees and their jobs [2].</li> <li>• Organizational trust and acceptance are critical: employees must believe that systems will be supported long-term, and organizations (especially SMEs) must assess whether adoption will be worthwhile for their workforce [4, 9].</li> <li>• Organizations should build resilience so they can adapt to external changes while maintaining human-centered priorities for employees [13].</li> </ul> | Ethics and societal responsibility |  |
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