Human-Centred AI in the Age of Industry 5.0:

A Systematic Review Protocol

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Abstract. Research within AI-based Industry 4.0 (I4.0) work systems has predominantly focused on technical and process performance, while human and psychosocial factors are rarely examined. These factors must be considered to design human-centred systems that cultivate sustainable human-AI interaction, i.e., human-AI interaction that promotes long-term well-being, engagement, and performance. The European Commission has brought forward a new vision of I4.0 called Industry 5.0, where well-being and technological advancement are jointly considered, thus overcoming the weaknesses of I4.0. To move forward with Industry 5.0, it is necessary to consolidate our knowledge of human-technology interaction within I4.0. This systematic review aims to uncover the antecedents and consequences of human and psychosocial factors within AI-based I4.0 systems, with an end goal of providing guidelines for the sustainable design, implementation, and use of these systems. This protocol presents the background and the methodology behind our review, as well as preliminary results and expected contributions.

Keywords: Human-centred AI · Industry 5.0 · Industry 4.0 · Psychosocial factors · Human factors

1 Background

Industry 4.0 (I4.0) is defined as strategies that are geared towards process, product, and service improvement through technology interconnectivity, decision-making speed, and automation capacity. Those strategies, in which artificial intelligence (AI) plays a central role, bring forward technological advancement expected to revolutionize manufacturing, operation, and production systems [1]. Improvements in technology undoubtedly lead to changes in the interaction between humans and the AI-based technology at the core of I4.0 [2-5]. Nevertheless, as shown by systematic and non-systematic literature reviews, I4.0 research has focused mostly on technical aspects of technology use and implementation, rather than the human within the system [4-6]. Manufacturing systems within I4.0 are socio-technical in nature, meaning that technical performance, human factors, and psychosocial factors must be considered to achieve system performance [4, 7].

The International Ergonomics Association [8] defines the discipline of human factors and ergonomics (HFE) as the evaluation of psychological and physiological principles related to the engineering of processes and systems. HFE is composed of three subdomains: cognitive, organizational, and physical ergonomics. Cognitive ergonomics deal with mental processes, perceptions, and cognitions; organizational ergonomics are interested in improving organizational processes and structures; and physical ergonomics, which fall outside the scope of this review, are interested in improving bio-mechanical, physiological, and anatomical aspects of work. On the other hand, psychosocial factors are defined as psychological constructs/variables resulting from the interaction between employees and their work environment. The most common psychosocial variables are work engagement, job demands, job satisfaction, and motivation. Although one could expect a certain overlap between psychosocial and human factors since they both examine humans in interaction with their work environment, psychosocial factors are generally not addressed within HFE literature. Rather, human factors research has mainly addressed sensory/perceptual, cognitive, and psychomotor processes instead of psychosocial processes, most commonly found with organizational psychology literature.

Despite an upward trend in research addressing HFE within an I4.0 context, most published research still solely focuses on technical or process performance [9]. In addition, despite long-established findings within organizational psychology demonstrating that psychosocial factors directly affect system performance, human performance, physical and mental well-being, psychosocial factors are largely ignored in I4.0 literature, which greatly limits our understanding of the human aspect of socio-technical interactions [10]. Both human and psychosocial factors must be considered in order to design human-centred work systems that foster sustainable human-AI interaction, i.e., human-AI interaction that promotes employee *long-term* well-being, engagement, and performance. To this end, the European Commission has brought forward a new vision of I4.0, called Industry 5.0 (I5.0), where human well-being and technological advancement are considered equally important [11]. In essence, I5.0 aims to overcome the weaknesses of I4.0 by creating human-centred work systems. To move forward with I5.0, it is necessary to consolidate our current knowledge about human-technology interaction within I4.0 systems. Within this optic, the current systematic review aims to: (1) determine which psychosocial and human factor outcome variables have been assessed within I4.0 systems; (2) determine the design, situational, or environmental antecedents of these variables; (3) determine how the antecedents affect psychosocial and human factors; and (4) provide human-centred guidelines for the sustainable design, implementation, and use of AI-based technology within Industry 5.0. Thus, we aim to answer the following research question: how can psychosocial and human factors be leveraged to create a sustainable human-AI interaction in the context of Industry 5.0?

2 Methods

PRISMA's checklist was used in order to ensure comprehensive and transparent reporting of this review [12]. We registered this systematic review with the International Prospective Register of Systematic Reviews (PROSPERO: CRD42022308729).

2.1 Eligibility Criteria

We have used the SPIDER Tool for Qualitative Evidence Synthesis, which provides guidelines to build a systematic search strategy properly adapted to address non-quantitative research questions [13] (see Table 1).

Table 1. SPIDER Framework

SPIDER Facet	Description
(S) Sample	We included research that discussed employees and users of AI-based technology in the context of Industry 4.0 or 5.0, and within a manufacturing or logistics setting. Additionally, we excluded all research involving humans with a neurological, psychiatric, physical disability, or under 18 years of age, as their findings may not be generalizable.
(PI) Phenomenon of interest	We included research that examined the use of AI-based technology by humans. In other words, we are interested in examining the human-AI relationship
(D) Study design	We included all types of research designs.
(E) Evaluation	We included research that discussed the impact of AI-related technology on the employee or user, in terms of psychosocial and human factors variables. Specifically, we looked for a meaningful discussion about human and/or psychosocial factors (motivation, engagement, stress, cognitive load, fatigue, well-being, empowerment, trust, acceptance, understandability, explainability, vigilance, work satisfaction, or usability).
(R) Research type	We included all types of peer-reviewed research in English, French, Italian, or German

2.2 Information Sources

The following databases were searched up to the 2nd of March 2022: Web of science, Engineering village (Inspec and Compendex), IEEE Xplore, ACM digital library, PsycInfo. Additionally, we conducted a backward and forward citation search for all studies selected for data extraction. ResearchRabbit, an online tool that provides articles' cited and citing references, was used. Authors were contacted when the full text was unavailable.

2.3 Search Strategy

Appendix 1 presents the full search query, which was used to search within titles, abstract, and keywords. The search query is separated into 3 subsections, separated by the Boolean operator "AND": subsection 1 includes domain/context-related terms (e.g., Industry 4.0/5.0); subsection 2 includes human and psychosocial factors and related terms (e.g., ergonomics, motivation); subsection 3 includes AI-related terms (e.g., intelligent agent, neural network). The search terms included in our query were found using a method commonly used in scoping reviews, which consists of 2

steps. Step 1 involves using the following search query structure: domain/context-related terms AND human and psychosocial factors. This search was conducted through each database. A maximum of 50 articles per database were examined (abstract and title) to derive any additional search terms that may have been missed in those 2 subsections of search terms. Step 2 involves using the following search query structure: domain/context-related terms AND AI-related terms. Once again, this search was conducted through each database, with a maximum of 50 articles being examined, with an end goal of finding any missing search terms.

2.4 Selection and Data Collection Process

Records were managed using Zotero bibliography manager and data was managed using multiple Excel spreadsheets, as well as Covidence, an online systematic review management platform. Duplicates were automatically detected by Zotero and were manually removed by one of the reviewers (MP). Two independent reviewers (MP and LD) were used for the title/abstract screening, the full-text screening, and data extraction. They were blind to each other's decisions. The decisions were then compared to each other, and inter-rater reliability was calculated. Together, the two reviewers examined the disagreements to try to come to a mutual acceptance. When necessary, a 3rd reviewer made the final decision.

2.5 Selection and Data Collection Process

The data extracted from each of the selected articles is shown in Table 2.

Table 2. Data extraction categories.

Section of article	Data extracted	Description
General information	Summary	Short summary of article
Introduction	Research question	Research question and research objectives
	Theoretical background	Theory discussed (e.g., sociotechnical systems theory, self-determination theory, Human-centered Design)
Methodology	Study type	Type of article (e.g., experimental, conceptual)
	Data collection method	Method used to collect data (e.g., survey/questionnaire, psychophysiology, performance measures)
	Variables manipulated/ antecedents	Independent variable manipulated or antecedents of outcome variable
	Outcome variables	Dependent variables addressed by the article authors through experimentation, discussion, or other methods.
	Technology used	Type(s) of technology used or discussed in the article.
Results	General results	A summary of the results
Discussion	Research gaps/ future research	Noteworthy points, such as research gaps, future research, and anything relating to the systematic review's research question

2.6 Risk of Bias Assessment

All records that pass screening will be independently evaluated by two reviewers (MP and LD) for bias in the experiment's design, conduction, and analysis using the JBI Critical Appraisal Tool. There are multiple JBI checklists, each for a different study type (https://jbi.global/critical-appraisal-tools). Thus, we will adapt our choice of JBI checklist based on study type (e.g., quasi-experimental, qualitative). Disagreements will be resolved via discussion. When necessary, a 3rd reviewer will make the final decision.

2.7 Synthesis Method

Due to the emerging nature of the field, we are expecting a significantly higher number of conceptual/theoretical articles, rather than experimental ones. Therefore, we expect to collect mostly qualitative data, rather than quantitative data. Thus, we have opted to synthesize data using a narrative synthesis to describe and summarize the main characteristics studies, and to unearth similarities/differences between studies. This will allow us to assess the strength of evidence [14].

3 Preliminary Results

Figure 1 shows the process through which we obtained our final set of articles for data extraction. A total of 36 articles have been selected. We are currently at the risk of bias assessment stage, which is the final step before full-scale data extraction.

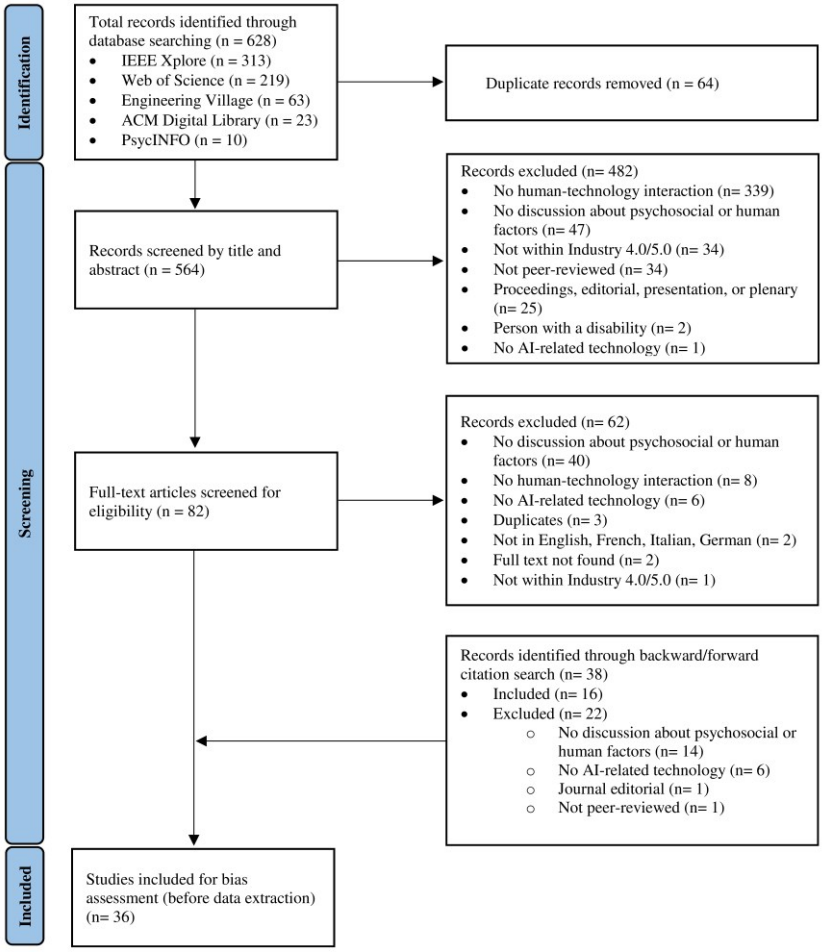

Fig. 1. PRISMA flow diagram

3.1 Inter-rater Reliability

Inter-rater reliability was calculated for the title/abstract screening and the full-text screening. As data extraction will begin shortly, inter-rater reliability will be calculated in the near future. For the title/abstract screening, the two reviewers (MP and LD) had a 90% agreement rate and a Cohen's kappa of 0.65, indicating substantial agreement. For the full-text screening, the two reviewers had an 86% agreement rate and a Cohen's kappa of 0.69, indicating substantial agreement.

3.2 Descriptive Data

Figure 2 breaks down the 36 selected articles by first author's university country. Italy, accounting for 25%, far surpasses other countries, which indicates that it may be a hub for human-centred

AI research within I4.0/I5.0. Figure 3 shows the distribution of the publication year of the 36 articles. It can be seen that the number of publications discussing human-centred AI within I4.0/I5.0 has been consistently increasing since 2018. When looking at publication outlet type, five of the 36 selected articles (14%) were published in conference proceedings, while the remaining 31 articles were published in journals. For these 31 articles, each of the following journals had 2 articles: *Computers & Industrial Engineering, International Journal of Environmental Research and Public Health, International Journal of Human-Computer Interaction,* and *Technological Forecasting and Social Change.* Other journals had one article each.

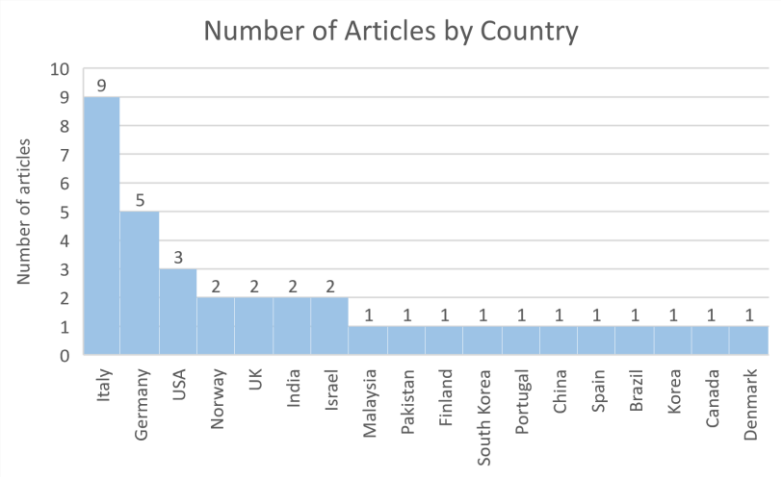

Fig. 2. Number of articles by country

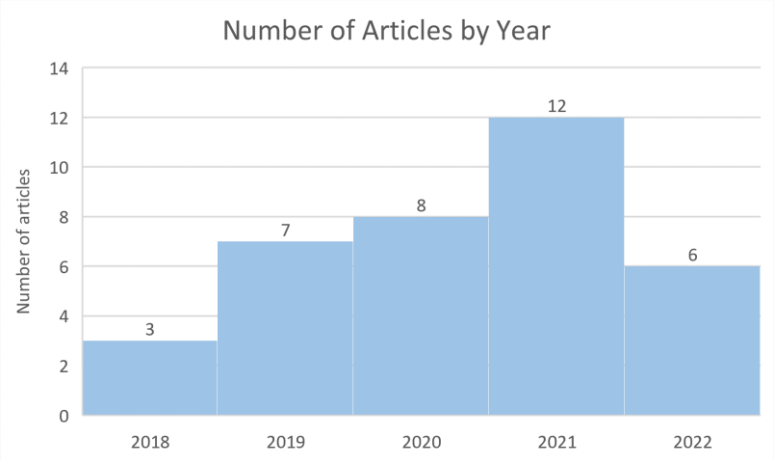

Fig. 3. Number of articles by year

3.3 Article Type and Data Collection Method

The 36 selected articles have been divided into four categories: (1) empirical, (2) review, (3) conceptual, and (4) system design and user test. Empirical refers to articles in which authors have collected data to answer a specific research question. Review refers to all types of literature reviews. Conceptual refers to articles in which authors have not collected data but have discussed a concept or framework. System design and user test refers to articles in which the authors present a system they have designed, followed by a user test. These user tests often have a very small sample size and often do not employ empirical methodology (e.g., no statistical analysis, no control group). Twelve on 36 were classified as empirical, 12 were classified as reviews, nine were classified as conceptual, while 3 were classified as system design and user test.

We also extracted the data collection methods used within the 12 empirical articles (Figure 4). While it can be expected that surveys/questionnaires represent the most used method, it is interesting that psychophysiological methods, such as heart rate, breathing rate, skin temperature, and electrodermal activity have been used on several occasions. Nevertheless, neurophysiological methods, such as electroencephalography and functional near-infrared spectroscopy, are notably absent.

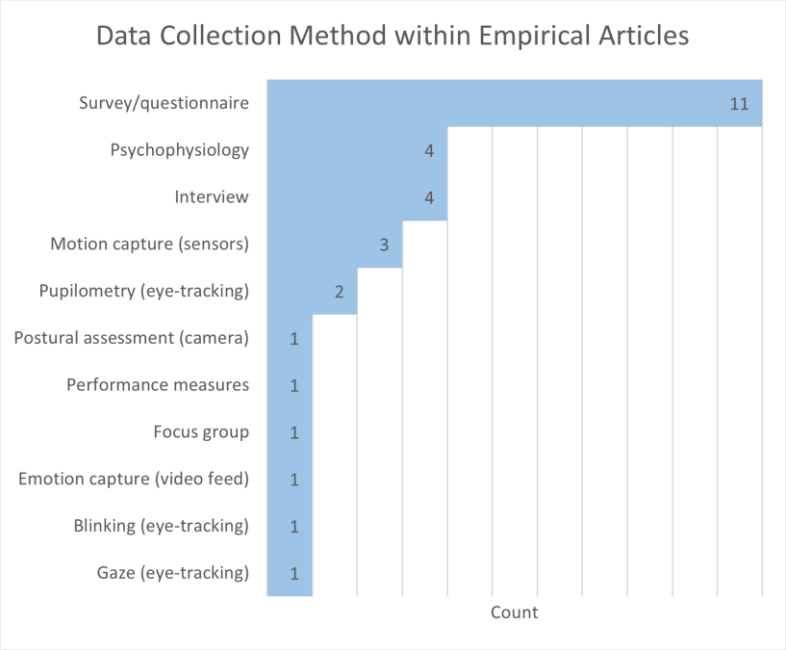

Fig. 4. Count of data collection methods within empirical articles

3.4 Expected Contribution

Through this systematic review, we expect to derive guidelines for the sustainable design, implementation, and use of AI-based work systems. In other words, these guidelines will aid to improve the long-term success of these systems by regarding human well-being as indispensable.

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Appendix 1: Search Query

“industr* 4.0” OR “industry 5.0” OR “smart manufacturing” OR “operator 4.0” OR “connected manufacturing”

AND

“human?cent?red” OR “user?cent?red“ OR “human factor*” OR ergonom* OR sociotechnical OR socio-technical OR anthropocentric OR psychosocial OR psychophysiolog* OR motivation OR engagement OR stress OR “cognitive load” OR “cognitive workload” OR fatigue OR “well being” OR well-being OR empowerment OR trust OR distrust OR acceptance OR acceptability OR personality OR comprehensib* OR understandab* OR explainab* OR vigilance OR “job satisfaction” OR “work satisfaction” OR Usability OR “User Experience” OR UX

AND

“artificial intelligence” OR AI OR ML OR “deep learning” OR “data mining” OR “machine learning” OR RL OR “reinforcement learning” OR “supervised learning” OR “unsupervised learning” OR “autonomo?s agent*” OR “intelligent agent*” OR “neural network” OR “machine intelligence”