The role of human factors in the human-centred design of service processes: a focus on the healthcare sector

Piffari, C.*, Lagorio, A.*, Cimini, C.* and Pinto, R.*

** Department of Management, Information and Production Engineering, University of Bergamo, Italy*

(claudia.piffari@unibg.it; alexandra.lagorio@unibg.it; chiara.cimini@unibg.it; roberto.pinto@unibg.it)

Abstract: The term "human factors" refers to all the elements – such as cognitive, physical, and organisational aspects – influencing human behaviour in the workplace. The field of human factors in industrial engineering is concerned with understanding interactions among humans and other elements of a system. It focuses on the design of tools, machines, systems, tasks, jobs and environments for safe, comfortable, and effective human involvement and interaction. Human factors are highly valued in complex systems such as aviation, nuclear power plants management, and manufacturing, and their relevance is also increasing within the service sector as well. This interest stems from the fact that human resources have become predominant in many companies' operations and objectives achievement. Consequently, considering human factors in process design and management has countless advantages. Taking into account human factors during the process design stage avoids the occurrence of problems afterwards. Human-centred process design has been proven to reduce errors and costs and improve quality and productivity. This work aims to make an appraisal of the perception, within the scientific literature, of the role of human factors in human-centred design in the service sector. In particular, the specific case analysed concerns the design of healthcare services, assessing the more relevant factors and possible evolutions of these factors. The choice of the human factors analysis in healthcare service is salient, especially considering that it is one of the services most affected by the Sars-Cov-2 pandemic.

Keywords: Human Factors, Human-Centred Design, Service Processes, Healthcare.

I. INTRODUCTION

Industry 5.0 is understood to recognise the power of industry to achieve societal goals beyond jobs and growth, become a resilient provider of prosperity, make production respect the boundaries of our planet, and place the well-being of the industry worker at the centre of the production process [1]. This transition derives from the consideration that Industry 4.0 focus more on digitalisation to improve efficiency and flexibility of the production and less on environmental and social sustainability [2]. Industry 5.0 complements the existing Industry 4.0 paradigm transitioning to a sustainable and human-centric industry. Focusing on a human-centric approach, Industry 5.0 is closely linked to the concept of human-centred design which has recently become one of the most promising approaches for improving the production process design. Human-centrality is a key concept also for the so-called Society 5.0, defined as a new concept aiming at creating a human-centred society in which products and services will be readily provided to satisfy various potential needs as well as to reduce economic and social gaps so that all the people live a comfortable and vigorous life [3]. A growing number of researchers, especially in ergonomics and human engineering, are addressing the domain of industrial engineering to ensure more human-centred manufacturing system designs [4]. To this end, it is also essential to consider the Human Factors (HF) involved in the various manufacturing processes. These concepts have recently returned to the attention of designers of manufacturing systems. However, they are not only applicable to the manufacturing industry, although it is currently the most investigated field. In fact, these concepts are gaining ground also in the service sector, where human-centred design makes it possible to prevent future issues caused by interaction problems between the operators and the system (i.e., physical environment, technologies, customers, other operators). Consequently, the analysis of HF can support the process of human-centred design. Within the service sector, the healthcare sector could particularly benefit from the concepts of human-centred design and HF. The HF consideration in the service and healthcare sectors is limited, particularly from a practical point of view. This is confirmed by numerous studies, including [5], demonstrating that physicians face one of the highest burnout rates of any profession in the United States and claiming for a re-thinking of healthcare service design towards more attention to HF. Moreover, successful healthcare

systems, achieved through human-centred process design, may allow delivering services that cut across organisational, political, geographical, and sectoral boundaries.

This paper aims to highlight gaps in the existing literature on HF in the healthcare sector that need further investigation. The main aim is to show how HF can help decision-makers in the healthcare process design and assessment. The manuscript is organised as follows: the context of the analysis is reported in section 2; the criteria used for the definition of the corpus for the literature review are reported in section 3; the analysis of the results is highlighted in section 4. Section 5 outlines gaps derived from the literature review. Conclusion and future work are addressed in the last section.

II. CONTEXT

In contrast to the strongly technocentric approach promoted by Industry 4.0, the Industry 5.0 paradigm has been proposed to provide a human-centred approach. Industry 5.0 puts core human needs and interests at the heart of the production and service processes. One way to achieve the objectives of human-centred manufacturing and service processes is to implement a human-centred design. According to International Organization for Standardization (2019), human-centred design is a multidisciplinary approach incorporating HF and ergonomics knowledge and techniques to make systems usable. Human-centred design revolves around discovering human needs so as to design products, services or production systems that meet those needs. Design is no longer used as a process to create physical products only but increasingly as a process that leads to the creation of any type of intervention that changes existing situations into better ones. This includes services, procedures, strategies and policies [6]. However, considering the needs of all stakeholders is difficult, especially in the healthcare industry, which involves multiple stakeholders who regularly have conflicting interests. In this sense, an approach that could be useful to overcome this complexity is Product-Service System (PSS). PSS allows developing services considering the needs of both operators and customers. For producers and service providers, PSSs mean a higher degree of responsibility for the early involvement of consumers in the design of the PSS. The PSS concept has the potential to accelerate the shift towards more sustainable practices and societies [7]. The adoption of a PSS-based competitive strategy uses product, process and customer knowledge to lead a more sustainable production paradigm [8].

The human-centred design discipline is closely related to that of HF, and the terms are often used interchangeably [9]. The term "human factors" refers to all the elements – such as cognitive, physical, and organizational aspects – influencing human behaviour in the workplace [10]. There is an increasing concern about how HF are barely considered in the design of products and services, causing complex problems with often unknown consequences across different industrial and service contexts [11]. Low attention to HF brings to unnatural positions, dangerous actions executed by workers during their jobs, and excessive tiredness and stress, with consequent lower performance, higher production time, more prolonged absence from work, and a general increase in the risk of physical accidents with a resultant impact on national economies [12]. Conversely, a human-centred design approach, taking HF into consideration, improves global performance compared to an exclusively techno-centred design approach [4]. A typical example of human-centred design is the creation of user-friendly interfaces to simplify the use of software for workers or general users. Broadly speaking, human-centred design refers to any product or service designed by involving users, trying to fully satisfy their needs and expectations. In these cases, the system's performance is no longer just about productivity but also about workers' and customers' satisfaction and well-being.

Moreover, another salient aspect of Industry 5.0 is the resilience following a catastrophic event disrupting the company's everyday activities. The Covid-19 crisis has highlighted the need to re-think existing working methods, approaches and processes with an aim to make their industries more future-proof, resilient, sustainable and human-centric [13]. This is particularly relevant for the healthcare sector, undoubtedly one of the sectors most affected by the Sars-Cov-2 pandemic crisis. However, even before the Sars-Cov-2 pandemic, few research works have been published on what a human-centred design approach entails when applied to healthcare organizations [6]. For this reason, in this paper, we review the scientific literature regarding HF in the healthcare sector to make an appraisal of the role of HF in healthcare processes' human-centred design and assessment.

III. METHOD

We analysed the literature on HF in the service sector and in the healthcare sector to scan all the relevant scientific literature about the current topic. The queries used were formulated to include as many papers as possible on this topic, and they were the following: ("human factor*" AND service AND operation* AND NOT "surgeon operat*") and ("human factor*" AND (healthcare OR "health care" OR medical OR clinical) AND (operator* OR worker* OR practitioner*)). We restricted the research only to the last ten years (from 2011 to 2022), in order to include and capture the evolution of the human factors in the healthcare service sector in the recent literature. We selected only scientific papers, conference papers, and reviews in the English language. The search was launched on the Scopus database, which is one of the most complete scientific papers' databases [14]. Additionally, we selected papers belonging to engineering, computer science, healthcare professional, business, management and accounting, decision science and multidisciplinary subject areas, excluding from the selection papers not related to the topic under examination, e.g., because they have an excessively medical focus. The first query produced 227 papers, and the second one produced 180 papers for a total of 407

selected papers. Reading the title and the abstract of the selected papers, we discarded 337 papers because they did not relate to the topics dealt with in this paper: HF were treated only marginally while the primary focus of the paper was different or because the HF analysis was not focused on healthcare service process but other types of services. Finally, reading each of the remaining papers, we discard 33 papers for the same reasons as before. From the remaining 37 papers, a snowballing process was carried out, which resulted in further 20 papers being added to the selection, for a total of 57 papers. These papers have been categorised according to the scope of the HF analysis. In addition, the HF discussed in each paper were inductively identified and extracted, in an effort to understand which factors have the most significant impact in the healthcare sector and which should be focused on for human-centred healthcare process design.

IV. RESULTS

A. Temporal distribution

It is possible to observe from the selected papers' temporal distribution that the interest in HF applied to the healthcare service sector has increased over the last ten years. A significant increase in research in this area occurred between 2020 and 2021, with 20 papers published. Despite the increased interest in applying HF in healthcare processes, significant problems in the practical integration and application of these concepts still exist. The healthcare sector is ideally suited to benefit from the domain of HF, however, several obstacles in their applications still exist. Among them, the healthcare sector was not designed as a system or as an industry, and the work of healthcare is difficult to bound to a precise setting [15]. Nevertheless, although these barriers result in a limited practical application of HF concepts to the healthcare sector, some examples can still be found.

B. Main topics

The fields of application of HF analysed in the selected papers are summarised in Appendix A, in which the main sub-topics covered in the papers are also listed. Eleven papers applied HF as components of risk management and prevention systems, i.e., as factors that could lead to medical errors and thus impact the health and safety of operators and patients. These models aim to prevent medical errors, which can be achieved with a renewed focus on the design of work systems and processes. Fourteen papers consider the effect of HF on medical errors without referring to specific models of risk prevention.

Besides risk prevention, the field of HF in industrial engineering is concerned with understanding interactions among humans and other elements of a physical system. This is particularly important for complex socio-technical systems such as hospitals and medical facilities in general, in which the physical environment can also impact the quality and success of the care process [32]. For this reason, it is also essential to apply HF in the human-centred design of physical environments where the care process takes place. In some cases, which are rather limited in the literature, HF have been considered to improve the workplace and the mainly physical but also cognitive comfort of healthcare workers, especially nurses. The field of HF focuses on the design of tools, machines, systems, tasks, jobs and environments for safe, comfortable, and effective human involvement and interaction. Particularly important in healthcare is the interaction and effective use of medical devices that can influence patient safety and the course of treatment.

There are also a few cases of the application of HF for the human-centred design of healthcare processes. [13] perform a systematic review of these cases summarising the evidence of HF application and demonstrating that these interventions consistently led to improvements in both health care workers' outcomes and patients' safety. There are many areas in which the application of HF knowledge can positively impact the delivery of healthcare not only from a safety perspective but also from an effectiveness and efficiency standpoint. These opportunities can be exploited in various areas: from the already seen applications for the design of equipment and physical plant design to process issues [33]. Indeed, complex socio-technical systems, like hospitals, are characterized by adjustments to everyday working environments and human performance. Understanding these adjustments and the trade-offs made by the healthcare workforce provides a realistic view of the source of variability and errors. Adopting an HF approach has enabled healthcare practitioners to understand better how work is done and why variability exists. In the most recent literature, fifteen papers assess the importance of HF in the care process of Covid-19 patients and, more generally in health care processes during the Sars-Cov-2 pandemic.

C. Human factors in the healthcare service sector

From the analysis of the papers described in the previous section, we inductively identified the most relevant HF in the healthcare sector. HF influence the achievement of the medical companies' objectives (i.e., patients' safety, operators' safety, treatments effectiveness). As anticipated, the International Ergonomics Association (IEA) characterises the field of HF ergonomics into three domains: physical, cognitive, and organizational [34]. For the analysis of the critical HF in healthcare, we decided to maintain the same subdivision. Additionally, since most of the literature on HF in healthcare does not go into the details of the three domains listed above and does not provide other alternative subdivisions, we decided to adapt the classes of HF identified by [35] for the logistic sector to the healthcare sector, eliminating HF not relevant in healthcare and adding HF not relevant in logistics but present in healthcare. The list of healthcare-relevant HF and their definitions are reported at the following link. We defined each HF based on the content of the listed papers. The literature has shown that the most critical HF in the healthcare sector are the organizational ones (Fig. 1).

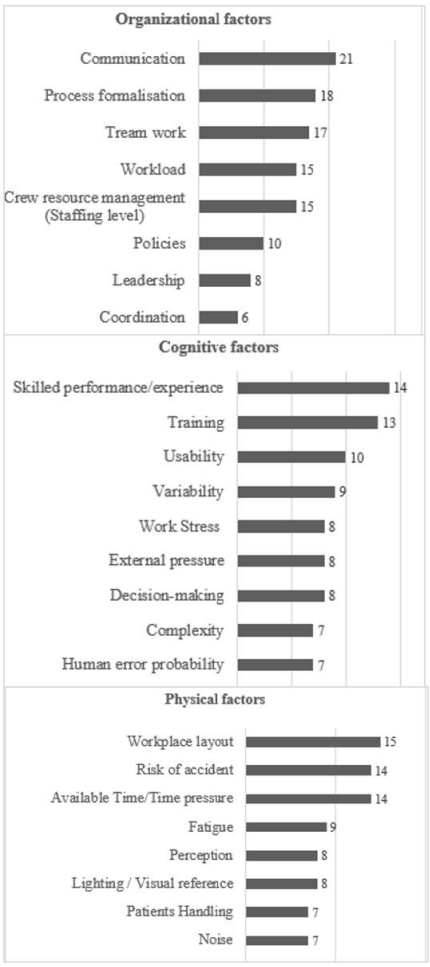

Fig. 1.Healthcare processes human factors

It is possible to observe that communication is cited as an HF affecting medical processes by 21 papers out of 57. Problems of communication within complex systems like healthcare are not new. The most common obstacles to clear communication are the fragmentation of the healthcare process, physical barriers and especially distraction and interruption [36]. Other organisational HF frequently mentioned in the papers are the formalisation of the process (cited by 18 papers), the need for teamwork (cited by 17 papers) and the workload and the staffing level (cited by 15 papers). That is to be expected because hospital activities are organised in departments with dedicated teams and highly formalised procedures to avoid legal battles in the event of adverse medical outcomes. In addition, hospitals are under enormous pressure to cut costs when faced with diminishing government subsidies and competition. Many hospitals have made drastic changes in response to these pressures, including cutting staff [37]. However, sustained levels of high utilization result in overwork, and the resultant decrease in productivity may offset any cost savings from operating at high utilization [38].

From the physical point of view, the most critical HF are the layout of the workplace (cited by 15 papers) and the risk of accident which could impact operators' and patients' safety (cited by 14 papers). On the other hand, cognitive factors are the ones least considered by researchers. Critical cognitive HF are the experience needed to perform the assigned tasks (cited by 14 papers) and the operators' training (cited by 13 papers). In the literature, less consideration has been given to the level of anxiety and alertness of workers and to the complexity of the work. As can be seen from Figure 2, interest in all types of HF in the scientific literature has increased: organisational factors have been taken into account in the design and management of healthcare processes in an increasing way since 2017. Concerning healthcare workers' physical and cognitive burdens, there has been increased interest from 2020 onwards. These two domains are essential for Society 5.0 and human-centred design of processes and services, as already mentioned in the context analysis.

V. DISCUSSION

From the previous literature review, we have identified the HF considered by researchers to be most relevant in the healthcare service sector. All three domains of HF have met with increasing interest from researchers. In addition, this interest increased significantly between 2020 and 2021 (Fig. 2), coinciding with the Sars-Cov-2 pandemic. This was predictable, especially as the healthcare sector and healthcare workers were the most affected by the Sars-Cov-2 pandemic crisis, being at the forefront of treating sick patients and implementing countermeasures, such as vaccination. In detail, the most significant increase in interest in HF occurred in cognitive factors. Several studies show that the levels of burnout, stress, anxiety and more serious psychological problems among healthcare workers increased significantly during the Sars-Cov-2 pandemic [39]. In addition to the psychological issues for workers, these cognitive problems also reflect on the medical organisation (e.g., higher absenteeism, higher risk of human error) and on the care process (e.g., lower quality). Going into more detail about the single cognitive HF, the literature shows an increase in external pressure on the operators due to the increased demand for medical services and the increased psychological pressure caused by the extraordinary situation [40]. This is demonstrated by the increased interest of researchers

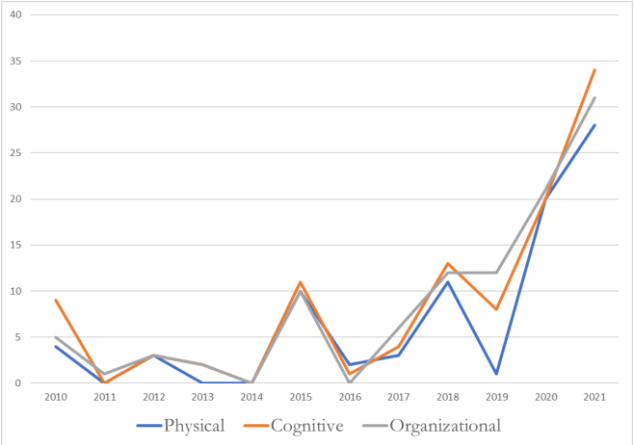

Fig. 2.Healthcare human factors' temporal evolution

in HF stress, workload, and anxiety. Decision-making also became much more challenging during the Sars-Cov-2 pandemic. At the tertiary level, hospital systems have experienced a significant surge in demand, which, combined with staff absences, places further stress on already overloaded tertiary healthcare networks. In these pressing times, humans are more likely to make mistakes in judgment and decision-making [41]. This, therefore, requires finding ways to identify and implement tools that allow for better societal preparedness and safety. The stressful situation is exacerbated by the fact that the healthcare systems, even under normal conditions, are extremely complex and therefore governed by stringent policies and procedures that guide decision-making. In front of an unknown pandemic, procedures and policies are constantly evolving, and it is difficult for operators to adapt to them.

Another cognitive HF that has attracted more interest is the concept of usability. In pre-pandemic papers, this factor referred to the ease of use and interaction with technology or medical devices. The meaning of this factor changed after the Sars-Cov-2 pandemic, referring mainly to the usability of personal protective equipment, especially masks, which can be a source of discomfort for operators if worn for a long time. A study [42] suggests that the use of personal protective equipment has perceptual and cognitive effects, in addition to physical and ergonomic influences. Efforts should be taken to mitigate the harmful effects of such influences, both regarding the performance of medical actions and the risk of contamination to health care workers.

From the physical domain point of view, the HF that have evolved with the Sars-Cov-2 pandemic and that have met with increasing interest are the risk of accidents, now explicitly understood as the risk of transmission of the virus to patients and workers instead of risks to general patients' safety. Additionally, in the scientific literature, there is a growing interest in operators' fatigue which was little considered in the pre-pandemic period [43].

Finally, from the organisational standpoint, problems of process formalisation and policy-making emerged: given the unique and unforeseen characteristics of the Covid-19 outbreak, a significantly increased demand for adaptation and/or expert improvisation without a predefined procedure was necessary [40]. There were also communication problems due to both physical barriers (i.e., personal protective equipment and limited access to critical areas) and the need for interdisciplinary collaboration to which the highly compartmentalised healthcare sector was not accustomed. The identification of these HF makes it possible to bring forth more targeted and suitable care actions for the management of the healthcare process but also for the design of an improved process. Figuring out how to design, implement, evaluate and redesign care processes in traditional situations or under novel disruptions to a working system is critical for rapidly evolving contexts [44].

These factors, especially cognitive factors, could have limited the adverse effects of the Sars-Cov-2 pandemic on health workers and health organisations that suffered major disruptions during the pandemic. Hospitals had to postpone most of their elective procedures while health workers experienced significant mental and physical problems [39]. HF leverage the knowledge of human capabilities and limitations. Including them in the human-centred healthcare processes design can improve both the work objectives achievement and the safety and well-being of operators and customers.

VI. CONCLUSION

HF acquired more importance in the manufacturing sector and then in the service sector. They are crucial to enable the human-centred design of the physical layouts, technologies, and processes operators interact with. One of the service sectors that could benefit most from such analyses is the healthcare sector, particularly after the Sars-Cov-2 pandemic. This paper reviewed the existing literature on HF applications in the healthcare sector, highlighting and defining the HF considered the most important by the scientific community for the healthcare service sector. This analysis also showed that the factors identified have evolved not only quantitatively but also semantically due to the Sars-Cov-2 pandemic, which has highlighted the lack of consideration of humans in the design and management of healthcare processes.

The results presented in this paper do have some limitations: the selected papers refer only to the last ten years, and consequently, there might be papers in previous years with relevant insights. In addition, this paper favoured a qualitative analysis of the selected papers and the identified HF; in future research, it might be helpful to also perform quantitative analysis and evaluate the methodological approach used in the selected papers. Further research should focus on filling these gaps and analysing how to integrate the relevant healthcare HF in the human-centred process design. Indeed, human-centred process design has been proven to reduce errors and costs, improve quality and productivity and significantly improve the safety and well-being of operators.

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Appendix A.

TABLE I
PAPERS' MAIN TOPIC

Field of application	Definition	Sub-topics	N
Risk management and prevention systems	HF application in risk management and prevention systems.	SEIPS model is a dynamic model which highly values the interaction between HF and system components for the patients' and operators' safety and quality of care [16].	11
Reduction of medical errors	Effect of HF on medical errors, without reference to specific models of risk prevention.	Assessment of HF, which might lead to errors in processes and consequently impact the success, quality, and safety of the care process.	14
Human-centred design of physical environments	Design of physical environments where the care process takes place.	• Ambulance design [17] • Emergency department design [18] • Intensive care unit design [19]	4
Impact on healthcare workers	HF consideration to improve the mainly physical but also cognitive comfort of healthcare workers.	• Physical problems [20] • Stress [21] • Workload [22]	5
Medical devices design	Human and medical devices interaction and effective use that can influence patient safety and the course of treatment.	• Diagnostic devices design [23] • Medical equipment's use [24] • Failures of medical devices [25]	3
Information and communication technologies design	Design easily accessible information and communication technology in the healthcare sector.	HF analysis in situations with a high-cognitive workload to improve requirement specification for the design of information and communication technologies [26].	4
Healthcare processes design	Inclusion of HF analysis in the design and management of specific medical processes.	• Blood transfusion sampling [27] • Patient handover [28]	6
Care processes during the Covid-19 pandemic	Assessment of the importance of HF in the care process of Covid-19 patients and more generally in health care processes during the Sars-Cov-2 pandemic.	• Covid transmission [29] • Cognitive burden [30] • Physical burden [31]	15