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Advantages and difficulties of implementing Industry 4.0 technologies for labor flexibility

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Abstract

Labor flexibility is widely recognized as a critical component of manufacturing flexibility to achieve a competitive advantage in the marketplace. This becomes more important in the context of Industry 4.0, where machines, products, components, Information, and communications technology (ICT) systems and workers collaborate to create an intelligent network. Several studies address the benefits of industry 4.0 technologies for workers. However, there is a concern about the future of work organization with the increased use of digital technologies and the extent to which these technologies allow flexibility or make workers' activities more rigid. Thus, this study aims to identify the advantages and barriers perceived by the operator in the implementation of these Industry 4.0 technologies. To achieve this objective, a literature review was performed. The results obtained show that Augmented Reality (AR) and Virtual Reality (VR) technologies increase flexibility since it provides the necessary information to carry out the work task and train operators, thus reducing the occurrence of errors and task duration. However, operator flexibility can also be affected, due to ergonomic aspects, the design of the system interface, as well as how these technologies are implemented. Collaborative Robots (CR) are an important instrument for flexibility, because the robot replaces the operator in the most demanding activities, leaving him available to perform other types of tasks and thus increasing his versatility.

Keywords: digital technologies; industry 4.0; labor flexibility; manufacturing flexibility

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1. Introduction

Currently, companies are facing a very unstable context, characterized by products with very short life cycles and unpredictable changes in demand. Therefore, flexibility has increasingly become an essential strategic competency [1]. Manufacturing flexibility is reflected in companies' ability to respond to market changes, without incurring high time and cost penalties [2]. Manufacturing flexibility is a multidimensional concept that can be implemented in different ways within companies depending on their strategic objectives [3]. An effective way to increase flexibility in a short time with a small investment is to prepare a multi-skilled worker [1].

Improved labor flexibility can be achieved through greater levels of process-focused training, job rotation training, and more reward practices based on greater skills [4]. In this sense, several studies have focused on understanding how the new Industry 4.0 technologies can support these training activities, as well as the daily work of employees. [5; 6]. Industry 4.0 technologies, allow greater flexibility and efficiency in complex assembly activities, product design, training, quality inspection, maintenance, and logistics activities, providing more information about these processes or physically supporting them [6; 7]. Nevertheless, Industry 4.0 also changes the work environment; the most significant change concerns the human-machine interface, which encompasses the interaction between workers and a set of new forms of collaborative work [8]. Furthermore, there is concern about how the implementation of these technologies will influence work profiles, as well as work management, organization, and planning [8; 9].

Considering this context, this study aims to achieve a better understanding of which will be the advantages and barriers to the implementation of the Industry 4.0 technologies, to improve the flexibility of the workforce. To answer this question, a literature review was performed, to analyse how the industry 4.0 technologies can support the flexibility of the workforce.

2. Theoretical Background

2.1 Labor Flexibility

Labor flexibility is defined as the number and heterogeneity of tasks that a worker can perform and the ability to vary the workforce within the company [10]. With flexible labor, a company can respond quickly to unexpected workloads that may arise. This kind of flexibility also allows the company to reduce job production times and improve customer service [2]. The results of [11], showed that employees' skills directly influence the flexibility of new products, volumes, and product mix, which in turn directly influence business performance.

The use of Information and Communication Technology (ICT) and cognitive automation has been discussed as an important tool to enable operators to perform complex tasks in manufacturing [12]. In recent years, with the development of digital technologies, which will lead us to the fourth industrial revolution, "Industry 4.0", the possibility of applying advanced technologies for efficient learning and training of workers in manufacturing systems has increased [13]. However, it is important to consider that manufacturing flexibility cannot be optimized simply by buying new and more sophisticated technologies. Instead, managers need to ensure an atmosphere that encourages employees to continually seek new solutions to get their work done and keep their skills up to date [11].

2.2 Industry 4.0 technologies supporting labor flexibility

Related with the labor organization, [13] stated that, Industry 4.0 technologies are changing the traditional organization of labor. The Smart Working, or Operator 4.0 paradigm, is related to a wide range of technical support needed by the worker in the manufacturing environment, which represents a challenge since there are several ways to improve the operator's activities and put him at the center of the current technological revolution [14; 15]. Physical and cognitive interaction is the most studied interactions between human and machine, with studies mainly focusing on three technologies, Augmented Reality (AR), Virtual Reality (VR) and Collaborative Robots (CR) [5; 8; 15],], which will be the focus of the present work.

Augmented Reality: is defined as a human-computer interaction tool that overlays digital information in the real-world environment in real-time [15; 16]. This technology can offer advantages to the operator since it allows displaying the necessary data for the worker, becoming a digital assistance system to reduce human errors [15; 17].

The application of AR systems is varied, they can support a variety of services, such as selecting parts in a warehouse or sending repair instructions via mobile devices [18].

Virtual reality is a human-computer interface that allows simulating different environments through a computational interface in real-time and multiple sensory channels, allowing user interaction with these environments [15; 19]. In the industry, VR technology can support the understanding of processes and the determination of parameters and variables based on the simulation [19]. According to [15], part models can be transformed into interactive virtual simulations to train operators in complex assembly tasks at the product assembly stage. Besides, it allows the visualization and virtual use of elements out of the user's reach and the safe use of hazardous equipment [21].

Collaborative Robots (Cobots): A robot is an artificial entity, either virtual or mechanical, that it is generally defined as an electromagnetic system that, due to its physical appearance or movements, gives people the impression of being a user of its own [6]. In workspaces, these robots interact with workers without the need for safety barriers [15]. These robots can increase productivity, flexibility and operator satisfaction, as they are a support to perform tasks involving manual handling of heavy elements or very repetitive tasks; consequently, the operators can focus on more valuable and interesting tasks [22; 23].

3. Methodology

This section describes the methodology adopted to perform the literature review, which allowed us to identify the advantages and barriers of implementing the technologies of industry 4.0. The research objective and the database of scientific articles that would be used were defined. Science Direct was selected because it is a recognized database with many articles indexed. The objective was to identify the advantages and disadvantages of using Augmented Reality, Virtual Reality, and Collaborative Robots for labor flexibility. The keywords selected to be used in the search were grouped into the following search string: “labor flexibility” AND, “Industry 4.0” OR “digital technologies”. Both databases search engine use both the UK and US versions of the labor word (labour vs. labor) and thus there is no loss of generality by using the word "labor" in detriment of "labour". The search was conducted based on the title, abstract, and keywords. In order, to include relevant articles in the sample, the “Snowballing” technique was applied. Only articles published in journals and conferences were selected.These latter, studied the labor flexibility focused on manufacturing processes. Moreover, we have eliminated articles focusing on the impact of digital transformation at the social and/or macro-economic level.

4. Results Analysis

The main results are presented in Table 1. In general, AR and VR technologies are used to provide the information needed to handle a specific situation or work task and to provide information about the product, process, or progress in production. The analysed studies, mainly focus on maintenance, inspection, and setup change activities [7; 24]. Related to worker training, both AR and VR constitute powerful tools. According to [19], through that training, the workers obtain the required skills for efficient and safe work without impeding production or consuming material. Besides, adequate immersion can improve operators’ perception and knowledge [20].

Although AR and VR appear to be technologies with the same purpose, it is important to choose well the technology to be used to ensure its efficient use by workers. In cases where a wide interaction between the worker and the real object is necessary, AR technologies are more useful than VR [7]. Therefore, VR is generally more appropriate in simulation activities, where the time for modeling is longer, and the AR is more appropriate for maintenance, in which the worker can superimpose images that he is virtually viewing with those of the real world [7].

Furthermore, [25] compared different types of AR technologies according to their advantages and disadvantages. The case of video-based glasses, optical glasses, and spatial projector, unlike the use of a tablet, leaves the operator’s hands-free, facilitating the agility of the operator’s activities. However, the video-based glasses can be heavy, causing some ergonomics problems and hampering operators’ activities. Image disturbance can be a difficulty caused by these technologies, as it can cause headaches and visual problems.

According to [16], an AR device suitable for a specific manufacturing problem is a very complex task due to its high technical skill and the use of necessary processes. An, AR system should be evaluated according to the system's ability to provide the correct information in different ways, in different contexts, as well as its responsiveness and agility. Furthermore, for these systems to be appropriate, the system must operate according to performance, based on the skills and factors that cause mental workload [17].

Table 1. Advantages and Disadvantages to technologies for labor flexibility

Technologies	Advantages	Disadvantages
AR	Provide information necessary to handle a specific situation or work task	Mental Workload, visual fatigue
		Users of the AR system mistrust the technology
	Virtual Training	AR delays workers due to distraction
	Improvement of cooperation between humans and another machine	Problems related to the user interface visibility and content
	Improve the safety and security of production systems	AR is redundant and high complex for solving the identified causes of errors
		Where there is little interaction between the user and the real object, there is little potential for AR
	AR: Video-based glasses. The operator's hands are free/ No problem of visual lag	AR: Video-based glasses: ergonomic problems related to the weight of the glasses; Coordination problems, due to incompatibility between what the user sees and what is happening in the real world
	AR: Optical glasses: The operator's hands are free/ The view of the real-world is almost intact/ Perceived efficiency increases in the task execution	AR: Optical glasses: Image updating as head moves is sometimes delayed/ Difficult to use if the user is already wearing glasses/ They become heavy after some time of use
	AR: Video-based tablet: Tablets are widely used, so people are already familiar with this technology	AR: Video-based tablet: To be able to visualize the information, the operator must hold the equipment with his hands / If the operator's hand or tool disturbs the camera, the virtual objects will disappear.
	AR: Spatial projector: The operator's hands are free/Do not t affect directly the operator's vision	AR: Spatial projector: Requires permanent installation of hardware equipment in the work environment / Information may become invisible if the operator or any tool interferes with the projection
VR	Provides information on product, process, and progress in production	VR is not useful if the user needs to interact with the real environment
	Virtual Training	Content for the user interface: The application must be able to select the content to show the user properly, based on his demands and situations that occur
	No programming skills required	
	Simulation of industrial operations and layout	
	(VR) offers the possibility to analyse a collaborative assembly	Human safety concerns: Head-mounted devices (HMD) might cause sickness during the use, especially in intensive applications/ Latencies, distortions, blurry images, among others, may cause health-related issues.
	The skills required for efficient and safe work are obtained without impeding production or consuming material	
CR	Enables new manufacturing skills through force-controlled movements	Human safety concerns: Risks associated with electricity usage/ Risks associated with entrapment and knockbacks
		Feasibility of the tasks to be performed by robots
	Higher efficiency by combining the endurance of robots and the high flexibility of humans	The information feedback channel from an industrial robot to a human worker is still limited
	Solution for Occupational risk factors (e.g. awkward postures, excessive effort, and repetitive movements)	The need to train operators and technicians on cobot maintenance and operation

VR is an important simulation tool, for improving processes and products, detecting possible errors during the planning phase of the new product development process, introducing a new layout, operator activities, and robot-human collaborative activities. In this sense, there are previous studies that have designed human-machine collaboration systems, where VR offers the possibility to analyse the risks associated with the system [19; 20]. Nevertheless, studies have shown that an important aspect of VR systems is the content of the user interface. In this sense, the application must be able to select the content to show the user properly, based on their demands and situations that occur [21]. Another difficulty that can arise is related to the safety of the human operator, the use over a long period of head-mounted devices (HMD) can cause health problems, as they stimulate the vestibular and visual sensory systems and latencies, distortions, blurred images, among others, can cause permanent health problems [20].

Regarding CR, this technology enables new manufacturing capacities and solves ergonomic problems, allowing the accomplishment of complex assembly tasks with less effort on the part of the worker [6; 26]. The use of collaborative robots can decrease the operation time leaving the workers with more time to focus on other activities. Moreover, according to [25] by combining the endurance of robots and the high flexibility of companies, it is possible to obtain greater efficiency. Also, CRs can be taught to perform new simpler tasks without the need to use programming experts [15].

However, one of the most common concerns related to the use of these robots is the safety of the worker [23]. In this sense, [22] stated that recognition of human movements could be used as input for the control of industrial robots. Although, the information feedback channel, from industrial robots to human workers, is still limited. These authors propose the use of AR technologies in a work support system for collaborative human-robot manufacturing [22]. According to [27], worker-robot cooperation is applicable when the final product requires a high degree of customization that a worker can provide, while cooperation with cobots can greatly accelerate productivity. In this context, one of the real problems is scheduling cooperative tasks in real-time between operational resources, e.g. workers and cobots. Furthermore, [28] stated that to implement a real collaborative work cell, it is not enough to buy a collaborative robot and accomplish safety requirements, it is also necessary to redefine the work cell and work organization methods in the establishment, especially work tasks.

Conclusions

This study aimed to identify the advantages and disadvantages of augmented reality, virtual reality, and collaborative robots to improve labor flexibility through a literature review. These technologies aim to optimize the workers' activities, reduce human errors, as well as reduce possible ergonomic problems. AR and VR are similar technologies, frequently used to simulate and provide production processes and the operator's tasks. However, decision-makers must carefully understand which are the necessary conditions to implement each of these technologies, to achieve the desired results. In addition, only a few studies analysed the real application of these technologies in the industry, most of them are conceptual models and possible applications of the technologies. In the case of the collaborative robot, there are still concerns related to worker safety and the communication channels between the machine and the worker. As future research, it will be important to develop empirical studies that demonstrate the real impact of Industry 4.0 technologies on the flexibility of the workforce.

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