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AMBIGUITIES OF INDUSTRY 4.0: GAINS, EFFICIENCY, AND WORKER TENSIONS

Georgiana Luna Batinga[1], georgiana@utfpr.edu.br, https://orcid.org/0000-0002-1807-9824
Richardson Coimbra Borges[2], richardson.borges@ufms.br, https://orcid.org/0000-0002-4404-2435

1 Federal Technological University of Paraná, 80230-901, Curitiba, PR, Brazil
2 Federal University of Mato Grosso do Sul, 79500-000, Paranaíba, MS, Brazil

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ABSTRACT

Purpose: Organizations are seeking technological innovations to improve their processes and production stages, configuring Industry 4.0, which, despite the evident gains, has generated tensions in the world of work. this article aims to analyze the strategies adopted by workers who experienced a process of technological innovation in the production line of a multinational organization.

Methodology/Approach: This study was conducted through a qualitative-descriptive approach, which investigated the perception of workers involved in organizations that went through technological innovations through semi-structured interviews analyzed using content analysis.

Findings: The results acknowledge the benefits of technological advancement to the substantial development of the production processes of these organizations but highlight the ambiguities of Industry 4.0, such as the replacement of human labor by machine, generating unemployment, conflicts, and tensions among workers.

Research Limitation/implication: The limitations of this study are the size of its corpus due to the difficulty in joining the research, imposed by the social limits caused by the pandemic.

Originality/Value of paper: The discussions observed in the research point to the ambiguities that accompany this phenomenon, which has different positions and visions and points to the urgency of inserting the human component in the debates involving various sectors of society.

KEYWORDS: industry 4.0. innovation. industrial performance. manufacturing technology.

AMBIGUIDADES DA INDÚSTRIA 4.0: GANHOS, EFICIÊNCIA E TENSÕES DO TRABALHADOR

RESUMO:

Objetivo: Cada vez mais as organizações buscam inovações tecnológicas para aperfeiçoar seus processos e etapas de produção, configurando a Indústria 4.0, que apesar dos evidentes ganhos, tem gerado tensões no mundo do trabalho. Dessa forma, esse artigo teve como objetivo analisar como trabalhadores inseridos nesse contexto vivenciaram essa transição.

Metodologia/Abordagem: Em termos metodológicos esse estudo foi conduzido por meio de uma abordagem qualitativa-descritiva, que investigou a percepção de trabalhadores envolvidos no contexto de organizações que passaram por inovações tecnológicas, por meio de entrevistas semiestruturadas analisadas à luz da Análise de Conteúdo.

Resultados: Os resultados reconhecem os benefícios do avanço tecnológico ao desenvolvimento substancial dos processos produtivos dessas organizações, mas ressalta as ambiguidades da Indústria 4.0, tais como a substituição da mão-de-obra humana pela máquina, gerando desemprego, conflitos e tensões entre trabalhadores.

Limitação/Implicação da pesquisa: Como limitações desse estudo aponta-se o tamanho de seu *corpus* em função da dificuldade na adesão da pesquisa, imposta pelos limites sociais ocasionados pela pandemia.

Originalidade/Valor do trabalho: As discussões observadas na pesquisa apontam para as ambiguidades que acompanham esse fenômeno, que tem posicionamentos e visões diferentes e apontam para a urgência de inserir o componente humano nos debates, envolvendo diversos setores da sociedade.

KEYWORDS: indústria 4.0. inovação. trabalho. ambiguidades. trabalhadores.

1. INTRODUCTION

Since the first studies on production processes in Administration, the importance of the human factor has been recognized in the composition of an organization's operational and productive cores (Neumann et al, 2021; Winkler et al., 2021; Robert et al., 2022). One of the first records in this regard was the Hawthorne experiment conducted by Elton Mayo in 1927, when employees of a factory were more productive when they noticed that the management paid particular attention to the working conditions to which they were subjected. Thus, whatever the segment in which an organization operates, it is necessary to recognize its human capital, which can become a differential in searching for satisfactory results. For, only through better use of the skills and competencies of its workers and the search for common goals is it possible to find a balance of interests in the relationships between organization and employee.

The challenges to achieving this desired balance of interests are not few because, with the growing and diversified supply of products and services, driven by the process of globalized technological evolution, it becomes increasingly sharper the customer's demand for qualities and attributes that add value to the product or service offered. These become mandatory requirements to be met to ensure the permanence of the organization in a constantly evolving and highly competitive market. In this sense, in the search for growth and improvement of their processes, organizations need to consider the worker as an ally who can contribute to these transformations, aligning technology and human capital towards organizational goals.

The term "revolution" already generates an expectation of breaking paradigms, so Industry 4.0 has change the social, political, and economic scenarios. Moreover, increasingly the world of work has been challenged to keep up with technological changes and innovations, using in its processes, among others, advanced robotics, fiber optic internet, artificial intelligence, cloud storage, Big Data, cyber-physical systems, machine-to-machine communication, and the intensive use of the internet in its various processes. These elements aim to maximize production and are called the fourth industrial revolution or Industry 4.0 (Xu et al., 2021).

Although this technological advance has brought substantial development to countries and organizations, it negatively affects the progressive substitution of human labor by machines, generating unemployment. On the other hand, there are still many workers who do not have the adequate qualification to adapt to this new reality and learn how to handle machines, computers, and all the modern apparatus that has been introduced in organizations, intending to minimize costs, time and productivity. The possibility of workers being replaced by robots is undoubtedly a concern because only one robot can take the place of several workers, which would result in a significant increase in unemployment. Naturally, this is seen as a concern for the worker. From the organization's perspective, however, such a possibility is an advantageous process, considering several factors, requiring only technical maintenance, ensuring agility and uniformity in production (Sanchéz-Castañeda, 2019).

This debate has important repercussions, this article intends to generate propositional reflections, understanding that it is possible to find a concordance of interests between worker and technology. It is essential to develop a systemic vision of how the technological process influences the organization's development and what can be done so that this advance occurs without neglecting its human capital. This discussion is crucial importance to an organization that intends to maintain its competitiveness, while it can affect the worker in adapting to new operational demands. Considering that this debate is mainly researched from the perspective of organizational gains and efficiencies, few studies choose to observe the theme from the worker's perspective inserted in this context, like Neumann et al. (2021), in “Industry 4.0 and the human fator: a systems framework and analysis methodology for successful development”; Sima et al. (2020), in “Influences of the Industry 4.0 revolution on the human capital developmente and consumer behavior”; Popkova & Sergi (2020), in “Human capital and AI in industry 4.0: convergence and divergence in social

entrepreneurship in Russia"; Torres et al. (2022), in "Development of a bussines assessment and diagnosis tool that considers the impact of the human factor during industrial revolutions", to name a few.

Thus, this article aims to analyze the strategies adopted by workers who experienced a process of technological innovation in the production line of a multinational organization. It is important to emphasize that when referring to technology, the article refers to new techniques, business models, insertion of machines, or even adjustments in the production process that aim to reduce costs and, or increase production.

In this sense, it is essential to emphasize that new technologies are considered those that break with the company's paradigms, either in the standard production model or through the previously effective strategies (Meindl et al., 2021). Thus, this article was conducted through a qualitative approach, bringing the perspective of workers of a particular multinational organization that has recently undergone a process of change and technological innovation. Besides this introduction, the theoretical framework presents the main concepts, characteristics, and elements that sustain Industry 4.0, followed by presenting the methodological path adopted in the research. Then, a discussion and analysis of its main findings are presented, asserting the adaptation strategies adopted to this new digital and transformational era, discussing a brief approach to the principle of this transformation in a general scope, and, finally, the final considerations.

2. LITERATURE REVIEW

2.1 Industry 4.0

The Fourth Industrial Revolution refers to the social, industrial, and technological changes caused by the digital transformation of industry, which are identified with the concept of Industry 4.0 (Wamba & Queiroz, 2022), which means the integration of intelligent machines and systems, associated with changes in production processes to increase efficiency and introduce the possibility of flexible changes in their scope (Machado et al., 2022; Grabowska & Saniuk, 2022). The Fourth Industrial Revolution is a term adopted to identify the social, industrial, and technological changes brought about by the digital transformation of industry. The nomenclature Industry 4.0 was adopted in Europe from the work of the German government to identify and analyze the disruptive changes of strategic importance for the country's economy. In this sense, Industry 4.0 can be considered an integral part of the Fourth Industrial Revolution, aggregating the interests of customers and companies in creating value and delivering high-quality products and services. The projection is to achieve intelligent monitoring and decision-making when companies and their networks can control and optimize their operations in real-time through production control methodologies (Grabowska & Saniuk, 2022; Ghobakhloo, 2020; Frank et al., 2019; Hermann et al., 2016).

The fourth revolution will not disseminate jobs, however, it will cause irreversible changes to the world of work, highlighting three points that deserve attention (ILO, 2016): 1) technological changes have changed the nature and quality of jobs, and may decrease jobs considered good and increase those considered bad; however, there will always be jobs (Butterick & Charlwood, 2021; Alam et al., 2020); 2) workers and companies will have to adapt to this transition process, taking into account that automation tends to increase gradually (Traulsen & Druedahl, 2018); 3) technological changes caused by the fourth industrial revolution may generate staggering gains in productivity, which will spark an increasing race towards industrialization (Brun et al., 2019).

Industry 4.0 is a coupling of automation and data sharing with manufacturing technologies and processes, including cyber-physical systems (CPSs), Internet of Things (IoT), cloud computing, cognitive computing, and artificial intelligence. The main advantages of Industry 4.0 include increased economic efficiency, increased labor efficiency, greater flexibility, reduced production

costs, and higher return on investment. Increased labor efficiency is achieved primarily through an automated decision-making process, while production is monitored, facilitating the creation and production of new products creating opportunities for flexible and intelligent production operation (Mendes et al., 2022; Grabowska & Saniuk, 2022).

According to Hermann et al. (2016), there are four guiding principles of Industry 4.0 are i) technical assistance (virtual and physical), ii) interconnection, iii) information transparency, and iv) decentralized decisions, which configure, based on academic and practical knowledge, the path that should be followed for the implementation and understanding of Industry 4.0. In this sense, according to Schuh et al. (2015), in the context of intelligent factories, there are three types of interactions:

1. Person - person, which is the interpersonal and administrative relationships
2. Person - machine, where human capital is responsible for the command order
3. Machine - machine, where the process is of total autonomy

The arrival of wireless networks made possible the interconnections between the most diverse equipment and the connection of these devices to the internet, making the great world computer network increasingly present in people's lives, with the emergence of the term Internet of Everything (IoE). This connection allowed information to be shared to achieve common purposes and to establish an interconnection through several devices, facilitating the fusion of the physical world with the digital world. Furthermore, this allows for information transparency, linking data collected from sensors with digitized models in production plants (Kagermann et al., 2015).

Furthermore, interconnection brings people and devices closer together, facilitating the flow of information. This interconnection promotes the decentralization of processes, while robots start performing unpleasant, repetitive, and unsafe activities that used to be performed by humans and are now spared from this wear and tear, in addition to maintaining a constant monitoring process, which facilitates adjustments to these changes and deviations in the tasks performed. This inevitably promotes a drastic change in the training and qualification of workers through effective interaction with these devices so that one can understand the large volume of information generated exponentially in real-time (Ghobakhloo, 2020; Khin & Kee, 2022).

2.2 Consequences of Industry 4.0

The implementation of new technologies causes impacts in all organizational spheres, from the administrative part to the management of processes and methods. The facilities and gains arising from this process seem sure, but the path may be painful until its improvement because the advances in gaining time, improvements in quality, ease of control, and adaptation, are accompanied by new demands for superior quality (Schwab, 2016). We can highlight the expected impacts change in the production and distribution processes of goods and services, the development of new consumption patterns, the creation of new demands by the market, the emergence of new business models, research increments, the development of information and communication technologies (ICT), new configurations in the labor market, among others (Tadeu, et al., 2017; Felsberger et al., 2022).

In this panorama, every transformation that aims for greater profitability or an aggregate of gains, such as time and quality, is seen as positive before the market, but for this to occur efficiently, it is inevitable to come across impacts that may represent losses for some. One of them is the progressive replacement of workers by machines, or even the exchange of face-to-face work for remote work, which will require technical knowledge to work under these new conditions, demanding the acquisition of new skills and abilities. In this context, there is also the replacement of repetitive tasks, previously performed by humans, which are now performed by automotive

processes (for example, the conveyor belt in the locomotion of products, forklifts, mass locomotion of goods) (Tadeu et al., 2017; Felsberger et al., 2022).

The evolution and adaptation to new industrial processes are of fundamental importance; however, it is necessary to consider the social aspect of this process, understanding the importance of human capital development in organizations. Although the processes are constantly evolving, they must be aligned with people, committed to the environment, preserving the fundamental exchange value that companies and employees have had since the beginning of industrialization. Technology is essential but not absolute, so it is essential to maintain the interrelation between technological development and human capital. In this sense, Industry 4.0 has several aspects that must be considered in its implementation: scientific, technological, economic, and social factors. To ensure a good association, the investment must result in a sustainable gain because processes need constant adjustments, and intelligent systems perform the more tasks, the less the demand for humans becomes (Meski et al., 2019).

In addition, it is currently necessary to consider the different demands of consumers who seek exclusive and high-quality products, which imposes a challenge to companies that must worry about meeting them without compromising production costs. Hence the importance of having a database involving customers to group consumers who have similar needs and desires will generate a gain in production scale without compromising the cost of a particular product/service. Furthermore, relevant aspects such as energy constraints, environmental resources, and social impacts should also be placed in the foreground, to the detriment of generating profits and growth, so that companies adopt a long-term perspective (Khin & Kee, 2022).

3. MATERIAL AND METHODS

The methodological path is understood as a stage consisting of defining, understanding, and evaluating the various choices made for academic research. Thus, this study is characterized as qualitative and descriptive research because it sought to understand a reality that cannot be quantified, of a subjective nature. Moreover, it was directed to analyze the perceptions of the subjects participating in the research, seeking to understand the social and human relationships, in a production of knowledge that takes place with the confrontation between the empirical and the theoretical used for the meaning of the research problem (Cruz & Medeiros, Batista Lins, 2021; Gonçalves, 2021).

In this sense, the data collection used in this study was conducted through the application of semi-structured interviews guided by a script of questions that considered responding to the objective proposed for this study (Guazi, 2021). To maintain the confidentiality of the participants, the interviewees were identified by the letter "I", an abbreviation of the word interviewee, followed by the numerical sequence of participants, such as I1, I2, I3. Furthermore, the workers who participated in the research were chosen by accessibility, considering the context defined for the research, i.e., all participated in the process of changes caused by the implementation of new technologies in the production process of the organization where they worked (Cardoso et al., 2021).

About the socio-demographic data, the participants are between 22 and 35 years old, most have completed high school, and some are in college. Their positions are related to the technical area, acting directly on the organization's production line, specifically in the sector of monitoring and inspection of quality and production management. With the permission of all participants, the interviews were recorded, transcribed, and then analyzed according to the steps provided by Content Analysis (Bardin, 2011). Following the steps of organization, reading, and identification of the most recurrent themes found in the interviews, the following thematic categories were identified: 1) Perspectives regarding the acceptance of new technologies in the work environment,

2) Perception regarding the process of adaptation to new technologies and 3) Unfoldings observed in the work environment.

4. RESULTS

As previously presented, the thematic categories were identified following the steps proposed in the Content Analysis of Bardin (2011), performed soon after the transcription of the recordings. The observation and reading of the interviews allowed the confrontation between the empirical findings and the literature review adopted in the article to understand the research problem. Thus, to answer the proposed objective and present a relevant discussion about the theme and its ambiguities, the worker's perspective was considered through reports about experiences experienced by the research participants in implementing new technologies in their work environment. In this sense, the most significant excerpts from the interviews were used to substantiate the discussions.

4.1 Perspectives on the acceptance of new technologies in the workplace

The set of reports analyzed in the interviews presented the perception of workers participating in the research about their experiences in the context of a period of implementation of improvements and technological innovation and adaptation to new working methods. Thus, in a majority, the participants recognize that technology is a benefit; however, "it depends on each one's ability to adapt" (E3). In the development of work relations, what became more evident was the ability to improve oneself to these new ways of conducting work, which represent a challenge, but also an opportunity for the development of new skills and competencies, as well as gains for the organization, according to excerpts transcribed below.

> I think that technology only comes in handy, to improve the performance of employees, customer service; because the market needs quick information (I1).
>
> I always liked it, I always sought improvements in this sense. I think technology comes a lot to help; the innovations (I2).

In the reports presented by participants I1 and I2, it is evident that technology is seen as something good, constructive, and that its function is to execute work processes better. However, it requires adaptations on the part of the organization and the part of the workers, who are faced with a new professional profile, as observed in the study by Sanchez-Castañeda (2019). Although they recognize technology as something that comes to add value to the operation, workers feel they are challenged to "be constantly improving so as not to be left behind, young people were born in the age of technology, and I am from the age of typing" (I1). In this statement, it is clear that they feel vulnerable because they are used to a system more dependent on direct human labor. In contrast to this, I2's account states that:

> The technology gives you a certain support (base), but you have to be feeding it, it makes it easier, but you always have to have the human side, to be filling in, completing the technological part with the manual (I2).

The fact that the present reports differences of opinion in certain aspects may be associated with the age of the workers because I2 is substantially younger than I1 and belong to different generations, and therefore have different worldviews.

4.2 Perception regarding the process of adaptation to new technologies

When approached about the ability to adapt to new technological processes inserted into the work environment, process format, and adequacy of the machine-man relationship, it is perceived as an essential factor, the constant search for a professional qualification, as well as the receptive attitude to what is "new" and that comes to contribute to the productive process. As can be seen in the transcribed excerpts:

> It depends on each person's ability to adapt, it also depends on the people who are going to instruct, it impacts each one in a different way, technology is made for people to adapt. Some people are not willing to learn. You always have to be ahead looking for new training. (I3)
>
> Some are being left behind, others are passing, people with more experience, but for not adhering to the technology issue they end up being left behind. (I1)

These statements correlate and generate an expectation of breaking paradigms, complemented by the thought of Schwab (2016, p.39), who says: "The implementation of new technologies will cause impacts in all organizational spheres, from the administrative part to the management of processes and methods. The evolution of processes proves necessary for the market to keep pace with the growing demands for distinctive and superior quality products and services and industrial and organizational processes that are in constant transformation. The consequences for those who fail to adhere to the new demands can be painful, as reported below:

> The people in my area have a culture that is more related to manual labor. I have experienced people who taught a lot of things, but because they didn't keep up with developments, they were passed on to younger people. There are people who can't adhere because they think that technology is unnecessary. (I2)

In the course of the interview, although the workers stated several times that they recognize the benefits of technology, it was possible to observe that at the beginning of the changes, in the most significant part of the implementation of technology, they were afraid because they did not know clearly how the process would take place. This fear is confirmed in Sanchez-Castañeda's (2019) study as an analogous point among the respondents when asked if they felt threatened by the new technologies. See the following accounts.

> In the beginning, yes. For not being prepared, but it is a matter of improving, of training. I saw people retire for not being able to adapt to new technologies, others lost space. (I1)
>
> As we have been preparing, understand and like this part, there are times when it seems like a threat, but as you are preparing and absorbing it well, it ends up gaining strength. (I2)
>
> In the beginning, yes, due to the fact that you are there and have to adapt. There is a certain fear (I3)

Through the reports presented, one can associate the conclusion of (Williamson et al., 2015), which points to a drastic change in the training and empowerment of people so that they can interact effectively with new technologies.

4.3 Developments observed in the work environment

With the interconnection and decentralization, the robots start to perform activities considered unpleasant, repetitive, and unsafe, previously performed by humans, as described by I3, "The machinery does the heavy lifting, thus having the reduction of manual labor (heavy lifting)." Seen as a positive point of this evolution, new technologies add value to production, despite the fear for those who can not adapt to these new processes. As the main factor of benefit caused by technology, the "agility in the processes" was mentioned (I1), where "the customer follows in real-time. It has only improved performance, speed, agility, and information", confirming what was found by Tadeu et al. (2017), which concludes that "among the expected impacts are changes in the production process and distribution of goods and services, development of new consumption patterns and customer needs, increasingly optimizing service and time at work."

Despite emphasizing the positive points, some negative points were mentioned, such as the decrease in jobs, since "20, 30 years ago, a job that five people did, today a machine can do it" (I2), agreeing that, despite the decrease in jobs, human labor will not be extinguished:

> For sure, the labor force is decreasing and giving space to machines, to technologies. Even though the technologies are always innovating, the human will always be connected to the machine. Because the machine will always need handling. (I2)
>
> The machine replacing is better for the company but unemployment increases. The human being ends up on the side, at least the one that does not want to join. (I2)

Despite fears about the reduction of jobs, the ease of the processes is of unquestionable acceptance among the interviewees, as cited by I3: "It helped a lot because of the ease, because before we had to do all the reports manually. Today we just enter the data in the application and print. It reduces the demand of time for this purpose". The reports agree with what is stated by the ILO (2016) when it says that "the fourth revolution will not spread out the jobs, but it will change the way they are done. It further states that technological changes have changed the nature and quality of jobs and may decrease jobs considered good; however, there will always be jobs. Thus, workers and companies will have to adapt to this transition process, considering that the trend only increases this gap. Finally, these changes provide staggering gains in productivity, which will demand an ever greater race toward industrialization.

5. CONCLUSION

This paper elected as its research theme Industry 4.0 and its ambiguities, a complex and multifactorial discussion, often approached from the perspective of contributions and benefits, highlighting only the gains it has promoted. To cope with such a rapidly changing environment, organizations constantly implement different technologies at different stages. This movement aggregates the digital transformation and the structural changes that have occurred in the economy, organizations, and society from the massive use of disruptive digital technologies and business models. The emergence of Industry 4.0 has brought with it several significant challenges and opportunities for organizations worldwide. The organizational perspective of digital transformation involves changes in organizational processes and business models and impacts the social aspect, as it refers to a phenomenon that affects all aspects of human life, including Workers involved in this process. The effects of these changes and their impacts on human life have been little problematized, and the parameters involved in this discussion are ambiguous (Meski et al., 2019) and constitute a challenge to organizations that must improve their methods to benefit from the

digital transition, thoroughly using this knowledge, considering all the singularities that accompany the phenomenon.

Indeed, digital transformation has become a topic of academic and business interest worldwide and has been researched mainly from the organizations' interests, while studies that prioritize the perceptions of workers involved in this context are still incipient. Because of this, this study aimed to analyze how workers inserted in a technological innovation process of a multinational organization experienced this process. The intention was to understand the phenomenon based on workers' experiences inserted in the context of transitions in organizational methods and procedures. Moreover, it also observed how these workers built adequacy and labor survival strategies in the face of the losses and challenges imposed by this process.

Thus, the main findings of this study consist of distinct positions that arose from the importance of inserting the social and human aspects into the debate because the world of work has been in constant transformation since ancient times. In ancient times, the discovery of new tools was fundamental to help the ordinary person and the artisans in their creations until the industrial revolutions that promoted deep transformations in organizations and work relations. Throughout history, it has been possible to observe that societies, processes, and work instruments have been improved to obtain greater productivity with less physical effort.

As previously stated, Industry 4.0 is a theme that arouses the interest of academics, politicians, entrepreneurs, society, and workers and has as its main characteristics the decentralization of work, the high speed in receiving data analysis, and the virtualization of processes; attributing changes in production processes and distribution of goods and services, the development of new patterns of consumption and customer needs, as well as the emergence of new business models. Despite this, the results of this study point to the recognition by workers of the substantial development of productive processes in organizations and their ambiguities and adverse effects, such as the replacement of human labor by machines, generating unemployment, doubts, and tensions among workers. There is also concern about the adaptation of workers who cannot keep up with these changes and are excluded from the labor market.

In this way, it is recognized that this is a theme that still finds space in debates and discussions that contemplate general interests of society, organizations, and academia and the public debate between government and agencies that represent the interests of the working class, recognizing its ambiguities. Therefore, as limitations of this study, the size of its corpus is recognized, since difficulties were encountered in the adhesion of the research, due to the social limits imposed by the pandemic, and due to the fear of some workers in participating in the study, despite the clarification of total anonymity. Thus, it is suggested that future studies on the subject may expand the number of research participants and may contemplate other sectors and segments of Industry 4.0, trying to observe possible differences in workers behavior and perception.

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DECLARATION OF CONTRIBUTIONS - CRediT

ROLE	GBatinga	RBorges
Conceptualization – Ideas; formulation or evolution of overarching research goals and aims.	X	
Data curation – Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use.	X	
Formal analysis – Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.	X	X
Funding acquisition - Acquisition of the financial support for the project leading to this publication.	X	X
Investigation – Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.	X	
Methodology – Development or design of methodology; creation of models.	X	X
Project administration – Management and coordination responsibility for the research activity planning and execution.	X	X
Resources – Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.	X	
Software – Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components.		X
Supervision – Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team.	X	
Validation – Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs.	X	
Visualization – Preparation, creation and/or presentation of the published work, specifically visualization/data presentation.		X
Writing – original draft – Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).	X	X
Writing – review & editing – Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.	X	X