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CONNECTED AND OVERBURDENED: HOW DOES INDUSTRY 4.0 IMPACT OCCUPATIONAL MENTAL HEALTH?

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Summary

Industry 4.0 brought technologies to manufacturing processes, creating Smart Factories. With this automation, some activities saw reduced physical demands, while the mental workload on operators increased. In this context, this article investigates the relationship between the fourth industrial revolution and occupational mental health. The objective was to present a Causal Loop Diagram (CLD), structured based on a Systematic Literature Review (SLR), that highlights the main connections between Industry 4.0 and mental health. The methodology was divided into four stages: (1) exploratory research; (2) SLR following the PRISMA protocol; (3) descriptive and content analysis; and (4) CLD development. The results indicated that: (i) adapting to new work demands became a source of stress; (ii) the use of collaborative robots increased productivity but created new cognitive demands and sources of stress; and (iii) stress is directly related to strain in task performance, anxiety, and mental exhaustion. It is concluded that the new roles and demands arising from the fourth industrial revolution may exceed the working capacity of workers, resulting in a direct relationship between mental stress and a decline in performance.

Keywords: Industry 4.0; Mental Stress; Mental Tension; Occupational Stress; Risk Analysis.

1. Introduction

Until the Third Industrial Revolution, workers needed to hone their manual skills and specialize in each operational action required for their workstation, resulting in less complex tasks (Blandino , 2023). With the introduction of new technologies into production systems since the Fourth Industrial Revolution (Industry 4.0), the complexity of production tasks has transformed, requiring new labor skills.

Intelligent automation and the digitalization process promoted by Industry 4.0 have reduced the physical strain on professionals. However, the accumulation of functions, the demand for new skills to perform new tasks, and the constant monitoring of new systems can

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cause stress among workers, due to more complex interfaces and continuous, real-time, and comprehensive assessment (Blandino, 2023; Hijry et al., 2024).

Furthermore, this increasing automation of manufacturing processes has generated greater mental load demands for workers, as it has demanded new work demands, such as prolonged vigilance, which require high levels of attention, resulting in peaks of stress and mental exhaustion (Wixted; O'riordan; O'sullivan, 2018).

Thus, the insertion of technology into processes can cause work demands to exceed the worker's capacity to execute or process them, increasing cognitive demands (Slazyk-sobol et al., 2021). This occurs because, although human factors are considered alongside technological aspects in the design of work environments, tasks have become increasingly cognitively demanding (Faccio et al., 2023; Rescio et al., 2023).

The scientific literature on the topic brings together research that explores the relationship between: (i) new working conditions and mental strain; (ii) digital work and stress levels; (iii) characteristics of work content and stress levels; and (iv) work content, strain, and performance (Kim; Kang; Park, 2021; Mariscal et al., 2023; Hijr et al., 2024; Klump et al., 2024). However, there is a scientific gap regarding studies that holistically relate the characteristics of Industry 4.0 to the mental health of professionals. Therefore, the introduction of methodological solutions, such as diagrams and frameworks, constitutes an important alternative.

Given this scenario, this article proposes the investigation of the relationship between the Fourth Industrial Revolution and occupational mental health. To this end, the overall objective is to present a Causal Loop Diagram (CLD), structured based on a Systematic Literature Review (SLR), that highlights the main relationships between Industry 4.0 and mental health.

DEC represents the qualitative approach of System Dynamics (SD), allowing a holistic view of the relationships between variables (Lucas et al . , 2024). To date, no studies have been found in the scientific literature that use this methodological approach to explore the relationship between the Fourth Industrial Revolution and mental health. Furthermore, this research contributes to the field by aligning with the Industry 5.0 paradigm, which places the human dimension at the center of systems design (Ma et al., 2025). Consequently, there is a growing demand for studies that address mental aspects, such as stress and occupational strain, with the aim of preventing occupational illnesses in new work contexts (Tran et al., 2023).

Structurally, this article is organized into five sections, in addition to this introduction. The second presents the theoretical foundation of this research; the third section presents the methodological procedures used; the fourth presents the results; the fifth presents the discussion; and finally, the sixth section presents the conclusions.

2. Theoretical basis

2.1. Industry 4.0 and Automation

The fourth industrial revolution is defined primarily by the interconnection provided by the Internet of Things (*IoT – Internet of Things)* and advances in the intelligent use of information, with technologies increasingly integrated into "Smart Manufacturing" *and automation* via the use of Artificial Intelligence (AI) in industrial automation (Adriaensen; Decré; Pintelon, 2019).

In addition to the aforementioned technologies, there is a growing trend in the implementation of augmented virtual reality and *big data technologies* (Blandino , 2023). Although automation has been implemented on a large scale, the presence of human workers is still indispensable in manufacturing industries (Tran et al., 2023).

Thus, Industry 4.0 does not only involve the adoption of new technologies and increased factory automation, but also the transformation of traditional jobs into networks that interconnect people, technologies, information and business units (Adriaensen; Decré; Pintelon, 2019).

The advent of the fourth revolution has profoundly transformed the paradigm of the industrial sector. Currently, a fundamental component of smart factories is the integration of cutting-edge technologies, such as *big data analysis* and predictive analytics, which offer opportunities to improve production and operational efficiency (Arif et al., 2024). Interconnected sensors, devices, and machines are used to generate ever-increasing volumes of *big data* , enabling pattern identification, process optimization, and improved product quality (Hijry et al., 2024).

As the amount of information generated in real time increases, algorithms and Artificial Intelligence systems that analyze this data and assist in decision-making are also being implemented and becoming increasingly necessary in Smart Factories. This leads to growing competitive pressure to implement solutions that promote competitive differentiation (Adriaensen; Decré; Pintelon, 2019).

In this new scenario, concerns arise about the health and safety of workers, who now face new work demands, whether due to replacement by automated robots or a shift in roles, moving from operating production lines to supervising manufacturing processes. This requires professionals to be able to interpret large volumes of information generated by machines, thus increasing levels of fatigue and mental stress in processes that traditionally would not require such exhaustive demands (Blandino, 2023).

Finally, we highlight the transition to Industry 5.0, which emerges as an evolution of the Industry 4.0 paradigm and stands out for promoting collaboration between humans and intelligent machines, with a focus on personalization, sustainability, and social well-being. It values the central role of humans in production processes, seeking to balance technological advances with social and environmental responsibility (Ma et al., 2025).

2.2. Mental health: stress and tension

In medical terms, stress is the human body's response to physical, mental, or emotional pressure, producing chemical changes that can accelerate heart rate, raise blood sugar levels, or increase blood pressure, thus highlighting physiological signs generated by stress. It can trigger feelings of frustration, anxiety, anger, or depression (Mariscal et al., 2024).

It can also be understood as the relationship between a person and their environment, such that the individual perceives an injustice, threat, or challenge that may compromise their well-being (Slazyk-sobol et al., 2021). According to the World Health Organization (WHO), stress occurs when job demands exceed workers' abilities, and this repeated exposure can result in acute or chronic stress, harming both mental and physical health (Tran et al., 2023).

The context of Industry 4.0, by subjecting professionals to new demands, generates uncertainty, increases the incidence of stress, and other mental factors. Constant surveillance work, for example, which is one of the new job demands, constitutes a source of mental workload, which quickly depletes workers' cognitive resources, generating high levels of stress and tension (Wixted; O'riordan; O'sullivan, 2018). Furthermore, Burnout Syndrome, a psychosocial phenomenon directly related to the work environment, has also gained notoriety. It provokes a negative subjective experience, triggering unfavorable thoughts, feelings, and attitudes toward work and the people with whom the worker interacts (Marques; Carlotto, 2024; Gil-Monte, 2010).

The consequences of this situation are harmful, resulting in reduced job satisfaction, increased absenteeism, and decreased worker productivity (Hijry et al., 2024). High levels of stress and tension can lead to distraction, causing production errors, workplace accidents, or loss of efficiency (Blandino, 2023).

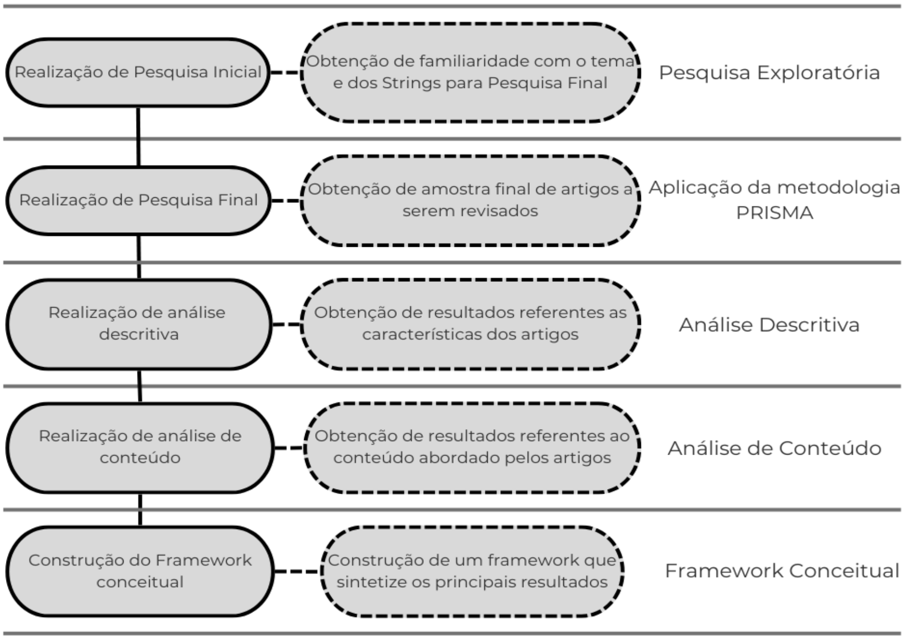
This negative correlation between mental health and worker performance is especially relevant because, as stress or tension increases, the quality of performance tends to fall and the time to complete tasks increases, generating negative impacts on the efficiency of the system (Blandino, 2023).

Therefore, it becomes essential to investigate the levels of stress, tension and other factors related to mental health in the workplace, in order to promote improvements in the health of workers, either by eliminating sources of stress or by offering adequate assistive support to mitigate existing levels (Mariscal et al., 2024).

3. Methodology

The adopted methodological framework was based on previous research (Bispo & Amaral, 2024; Tan et al., 2023; Blandino , 2023) and was subdivided into five stages, as shown in Figure 1. Initially, exploratory research was conducted on the topic. Next, a Systematic Literature Review (SLR) was developed using the PRISMA methodology. Subsequently, Descriptive Analysis and Content Analysis were structured. Finally, a conceptual *framework was developed* to highlight the main relationships found between Industry 4.0 and mental health.

Figure 1: Methodological steps for developing the research



Source: Own authorship (2025)

3.1. Exploratory Research

Exploratory research was conducted to provide greater familiarity with the problem under investigation and, most importantly, to assist in defining the *strings* that would be used in the SLR. This step is important because it allows researchers to define search terms effectively, positively impacting the development of the review (Bispo & Amaral, 2024).

Initially, an exploratory search was conducted in the *Web of Science* and *Scopus databases* , linking the two groups shown in Table 1. These databases were chosen because they are used in other research (Bispo & Amaral, 2024). Group 1 included terms related to Industry 4.0, while Group 2 included terms related to Mental Health. The groups were associated using the OR operator to identify as many articles as possible related to each group and, from this, determine the ideal set of keywords.

Table 1: Initial Search *Strings*

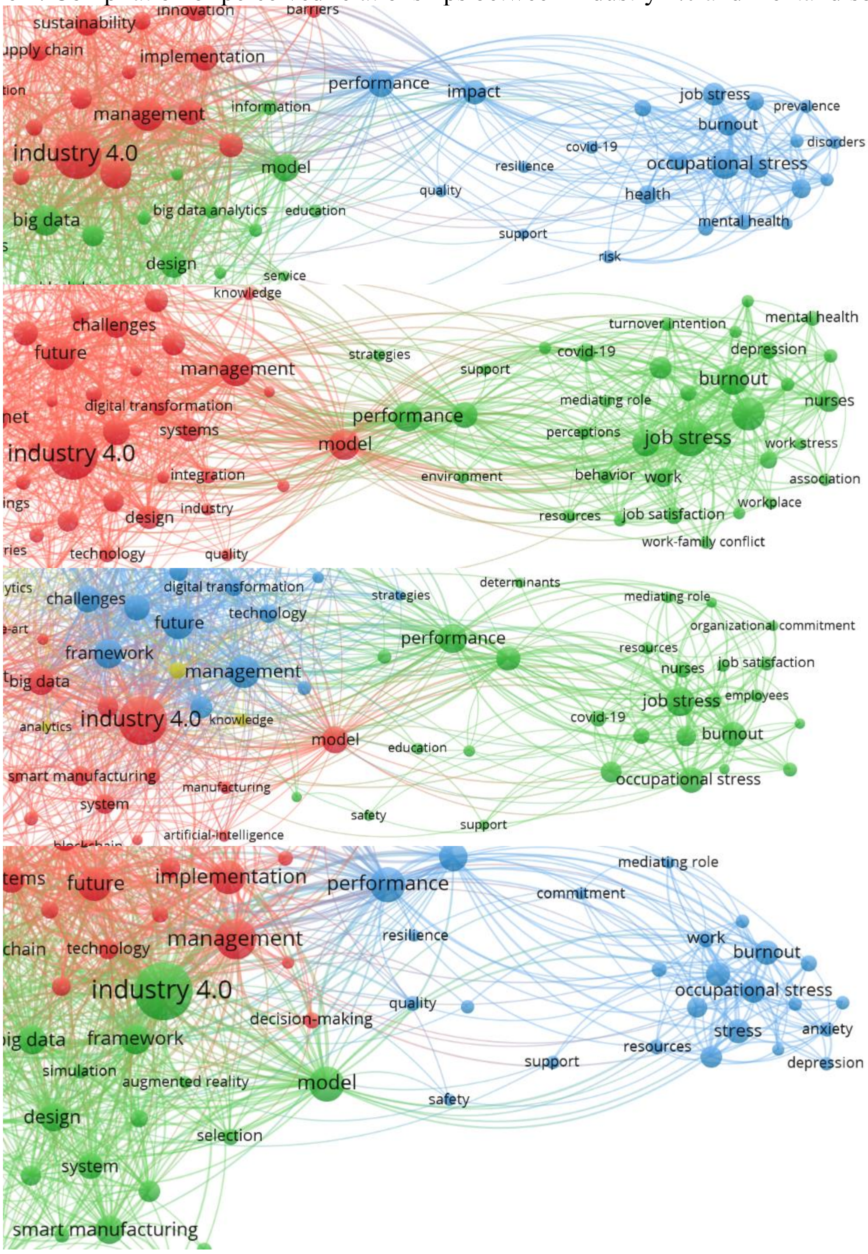
Group 1: Industry 4.0	Group 2: Mental health
(“*Industry 4.0” OR “The fourth industrial revolutions” OR “the 4th industrial revolution” OR “Smart Factory” OR “Smart Manufacturing” OR “Factory 4.0” OR “Smart Production” OR “Manufacturing 4.0” OR “Smart Industry” OR “Logistics 4.0” OR “Quality 4.0*”)	(“*Occupational Mental Disorders” OR “Workplace Psychological Disorders” OR “Mental Health Disorders in the workplace” OR “Occupational mental Health” OR “Workplace Mental Health” OR “Mental Health in workplace” OR “Occupational Anxiety” OR “Work-related Anxiety” OR “Job Anxiety” OR “Workplace Anxiety Disorder” OR “Occupational Depression” OR “Workplace Depression” OR “Occupational stress” OR “Job stress” OR “Workplace Stress*”)

Source: Own authorship (2025)

Using these search terms, 7,628 documents were identified in the *Web of Science* and 9,492 in *Scopus* . There was no restriction by time period, document type, or language. The lack of inclusion or exclusion criteria at this stage was intentional, aiming to provide researchers with the largest possible number of documents.

Using this sample, a network analysis was performed to verify the association of keywords in the articles. This analysis was performed with the help of VosViewer software and is represented in Figure 2. The procedure allowed us to identify two aspects: (i) the formation of *clusters* related to Industry 4.0 and mental health, which were connected, and (ii) the identification of new keywords that were not considered and established in the first search.

Figure 2: Compilation of perceived relationships between Industry 4.0 and mental disorders



Source: Own authorship (2025)

By identifying these new keywords through network analysis, the best combination of terms for performing the SLR was defined. Table 2 presents the two groups, highlighted in red to highlight the newly incorporated terms. These two groups were connected using the AND operator, as the goal was to identify articles that related the two thematic sets.

Table 2: Definition of *strings* for Final Search

Group 1: Industry 4.0	Group 2: Mental Health
("Industry 4.0" OR "The fourth industrial revolutions" OR "the 4th industrial revolution" OR "Smart Factory" OR "Smart Manufacturing" OR "Factory 4.0" OR "Smart Production" OR "Manufacturing 4.0" OR "Smart Industry" OR "Logistics 4.0" OR "Quality 4.0" OR "4.0 industry" OR "Industrial revolution 4.0" OR "4.0 revolution" OR "Operator 4.0" OR "Fourth Industrial Revolution" OR "Healthcare 4.0" OR "Automated Manufacturing")	*("Occupational Mental Disorders" OR "Workplace Psychological Disorders" OR "Mental Health Disorders in the workplace" OR "Occupational mental Health" OR "Workplace Mental Health" OR "Mental Health in workplace" OR "Occupational Anxiety" OR "Work-related Anxiety" OR "Job Anxiety" OR "Workplace Anxiety Disorder" OR "Occupational Depression" OR "Workplace Depression" OR "Occupational stress" OR "Job stress" OR "Workplace Stress" OR "Worker Stress" OR "Workplace mental health and stress" OR "Workplace mental Stress" OR "Workers stress" OR "Indicative of workers stress" OR "Worker stress levels" OR "Stress management" OR "Stress measurement" OR "Occupational Safety" OR "Workplace safety" OR "Time stress" OR "Working stress" OR "Mental stress" OR "Quantify stress" OR "Psychological stress" OR "Stress Feeling" OR "Experienced stress" OR "Stress factors" OR "Sense of stress" OR "Stress levels" OR "Work-Related Stress")*

Source: Own authorship (2025)

After defining the search terms in the exploratory research, the RSL was carried out.

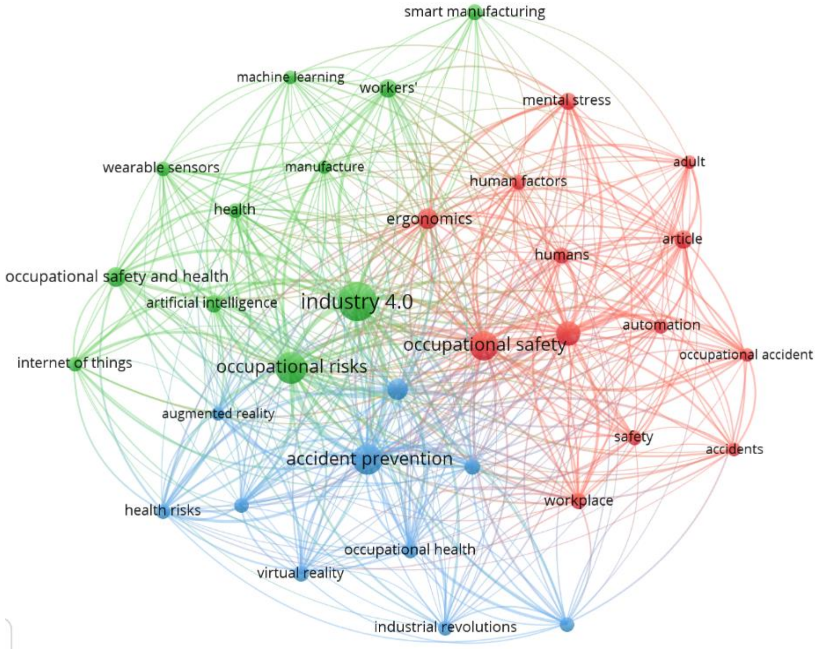
3.2. Systematic Literature Review (SLR)

The Systematic Literature Review (SLR) was developed from the *Preferred protocol Reporting Items for Systematic Reviews and Meta- Analysis* (PRISMA), which is used to provide an appropriate guideline for including articles relevant to the discussion of the topic, through four selection stages: Identification, Screening, Eligibility and Inclusion (Tan et al., 2023; Blandino , 2023).

Before beginning its structuring, the guiding questions of the SLR were established, as specified in the study developed by Bispo & Amaral (2014). Three questions were formulated: (1) What are the main aspects of mental health that can be influenced by Industry 4.0? (2) What methods are being used to assess the influence of Industry 4.0 on mental health? (3) How does the relational interaction between Industry 4.0, mental health, and performance occur?

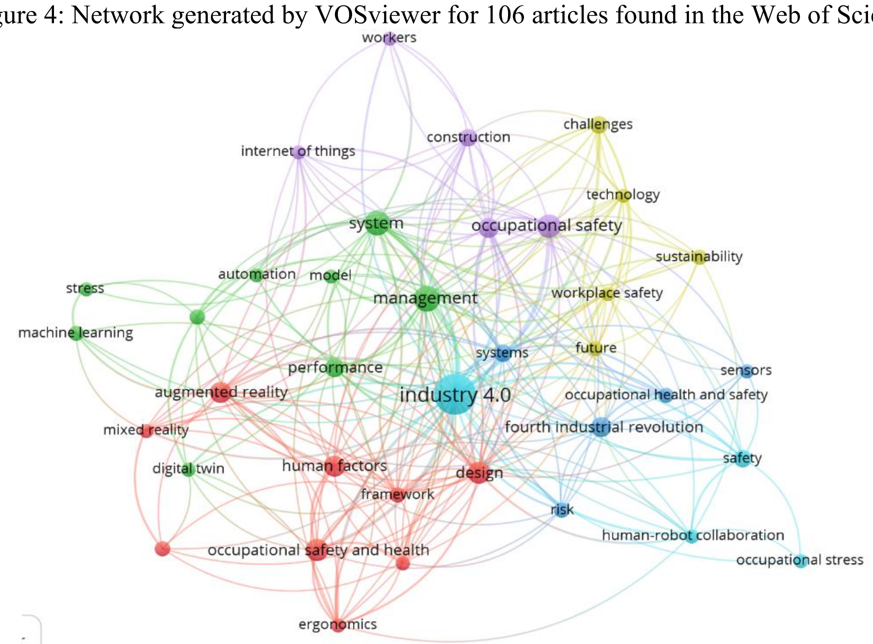
The search terms defined in the exploratory research were used in the Web of Science and Scopus, chosen because they are widely used in similar studies (Bispo & Amaral, 2024). The search, which did not include any exclusion criteria or time limits, resulted in 106 documents in the Web of Science and 203 in Scopus, totaling 309 documents. To verify whether these samples effectively covered both groups, keyword networks were generated in the VOSviewer software , as illustrated in Figures 3 and 4.

Figure 3: Network generated by VOSviewer for 203 articles found in Scopus



Source: Own authorship (2025)

Figure 4: Network generated by VOSviewer for 106 articles found in the Web of Science



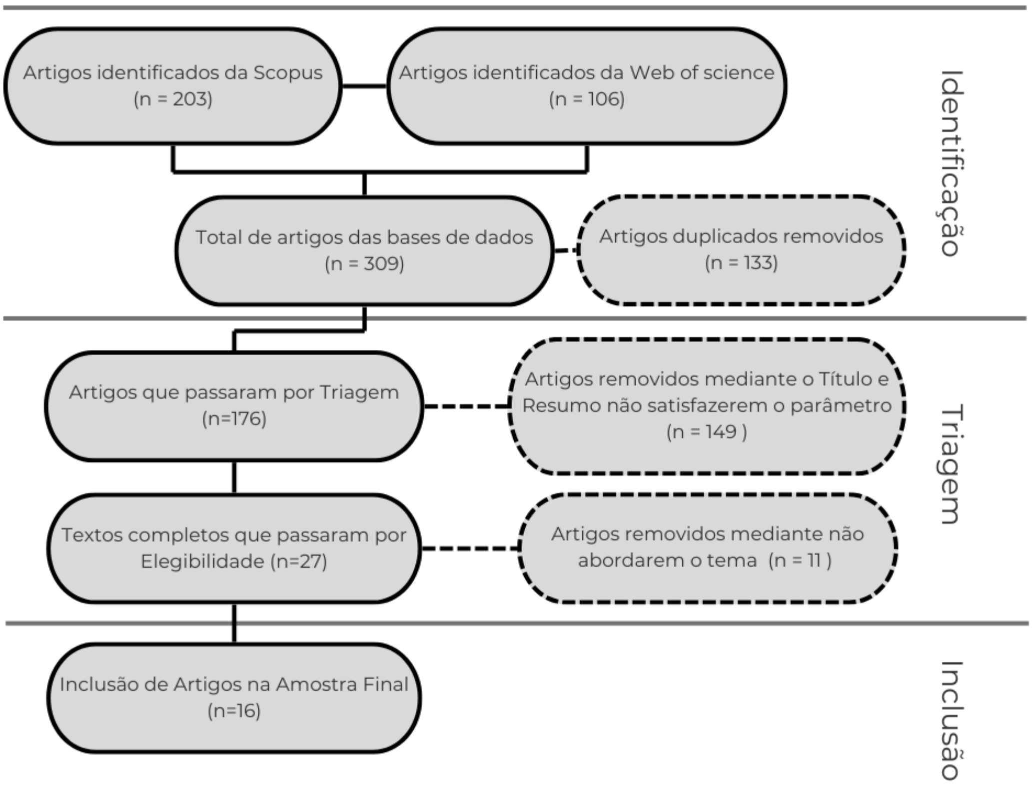
Source: Own authorship (2025)

For better sample management, the 309 articles were imported into the Mendeley Software Reference Manager. Duplicate removal was then performed to eliminate duplicate documents from the sample. After this removal, the sample was reduced to 176 articles.

Subsequently, a screening process was performed by analyzing the titles and abstracts of each article. The following inclusion criteria were adopted: the article had to objectively address the relationship between Industry 4.0 and mental health. Therefore, articles that addressed only one of the topics or did not integrate them were classified as "outside the scope of the research." After this screening process, 149 papers were excluded, leaving a sample of 27 articles.

The final screening stage consisted of a full reading. At this stage, two criteria were applied: (i) the article had to be published in a journal, and (ii) the article had to objectively address the relationship between Industry 4.0 and mental health. After this screening, 11 articles were excluded, resulting in a final sample of 16 documents. Figure 5 shows how the Prisma protocol was implemented.

Figure 5: PRISMA protocol application flowchart



Source: Own authorship (2025)

After selecting the final sample, descriptive analysis and content analysis of the articles were carried out.

3.3. Descriptive and content analysis

To perform the descriptive analysis, we used the procedure presented in Table 3, through which information was extracted to characterize the articles, such as title, authors, place of publication, year, author, and journal. The objective of this analysis was to provide an overview of the sample, highlighting aspects such as the distribution of publications by year, country, continent, and the journals in which the articles were indexed.

Table 3: Structure for performing Descriptive Analysis

Title	Authors	Year	Magazine	Type of magazine	Country

Source: Own authorship (2025)

To complete the descriptive analysis, two networks were structured in VOSviewer software . The first aimed to analyze the relationship between keywords that were cited at least once. The second aimed to perform the same analysis, but the keywords had to be cited at least twice. The two analyses are complementary and necessary to provide greater consistency in identifying existing relationships.

Content Analysis was performed after descriptive analysis, through the creation and completion of Table 5, with the aim of highlighting central information of the articles: (i) study objectives; (ii) methodological procedures (profile of research subjects, location, analysis method, methodologies used); (iii) results (all relevant points related to the research topic); (iv) main conclusions of the study (related to the research topic); (v) suggestions for future research; and (vi) evaluation of the relationship with the research topic.

Table 4: Structure for performing Content Analysis

Title	Objectives	Methodological Procedures	Results	Main Conclusions	Suggestions for future research	Assessmen t

Source: Own authorship (2025)

Based on the information obtained in the previous steps, it became possible to analyze how Industry 4.0 relates to mental health. To synthesize the results, a conceptual *framework* was structured to graphically and holistically represent the relationship investigated in this research. To achieve this, the Causal Loop Diagram (CDD) was used as a methodological procedure. This is the qualitative approach of System Dynamics and is used to represent cause-and-effect relationships between variables.

4. Results

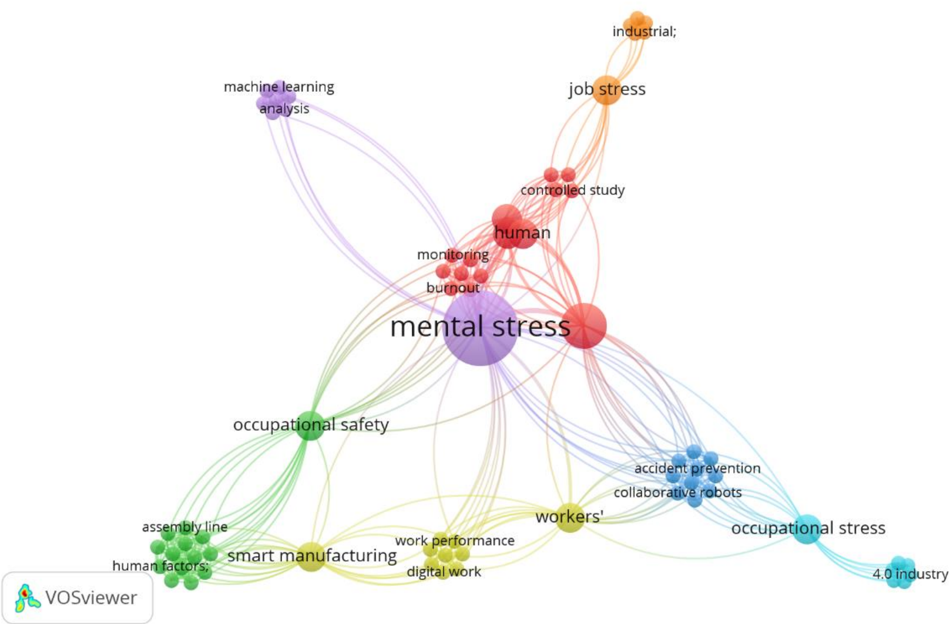
When analyzing the sample obtained, it was observed that scientific interest in the topic has been growing in the last two years, with 9 articles (56%) published in this period. The number of articles published in 2023 (n=5 articles) and 2024 (n=4 articles) was, respectively, five and four times greater than the number published between 2019 and 2022.

Geographically, most studies were conducted and published in European countries, comprising 76% of the sample, followed by 18% in Asia and 6% in North America. Among the ten countries represented in the sample, nine have an average population age over 40, which is significant because, as individuals age, their years of experience in operational tasks increase, making it difficult to adapt to and use new technologies. This leads to greater demands and overload on workers, resulting in mental fatigue (Rescio et al., 2023; Slazyk-Sobol et al., 2021).

4.1. Network analysis

Figure 6 shows the co-occurrence network of keywords mentioned at least once. Overall, mental stress appears at the center of the network, with five directly connected clusters. Specifically, regarding mental health, terms such as mental stress, occupational stress, job stress, job performance, and burnout syndrome are observed. Regarding Industry 4.0, the following terms stand out: smart manufacturing, machine learning, digital work, collaborative robots, and Industry 4.0.

Co-occurrence network (1 time) of keywords



Source: Own authorship (2025)

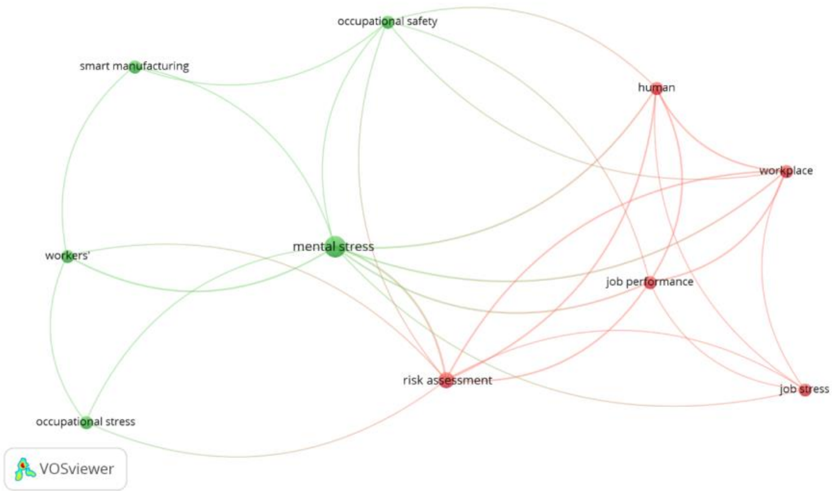
Among the key connections observed in the network, the following stand out:

- Smart manufacturing is directly related to digital work, the assembly line and more advanced technological structures, such as the Internet of Things (IoT).
- Both smart manufacturing and digital work are directly linked to job performance, which in turn is linked to mental stress.
- Work stress or occupational stress is directly connected to Industry 4.0 and the use of collaborative robots.
- The use of collaborative robots is directly related to workers, which are also connected to job performance and mental stress.
- Mental stress is directly linked to burnout syndrome, tension, anxiety, and depression, all connected to human factors, as well as monitoring and analysis processes.
- Machine learning and collaborative robots are directly connected to risk monitoring and assessment.
- Risk assessment is directly related to human factors, occupational safety and workers, in addition to being interconnected with monitoring and controlled studies.

Figure 7 illustrates the co-occurrence network of keywords cited at least twice. This network emphasizes those with the greatest prominence. Key relationships include:

- Smart manufacturing is directly connected to mental stress.
- The workplace is linked to job performance, which in turn is linked to mental stress.
- Workers are directly connected to both mental stress and occupational stress.
- Human factors are directly related to mental stress, job stress and job performance.
- Risk assessment is directly related to occupational safety and job performance, and is also interconnected with occupational stress, work stress, and mental stress.

Co-occurrence network (2 times) of keywords



Source: Own authorship (2025)

4.2. Content analysis

4.2.1 Analysis by individual factors

The study developed by Klumpp et al. (2024) demonstrated that professionals with an average age over 40 years (41.65 years) were being subjected to a greater mental load compared to the physical load, when faced with new transformations in the work environments. It was identified that 76% of the work performed by the sample consisted of mental work and 24% physical work (Klumpp et al., 2024).

Knowing the average age of the sample allows us to identify whether the professional profile analyzed was subjected to working conditions prior to Industry 4.0, a period in which greater physical demands predominated than cognitive ones. This is relevant because professionals with more experience, acclimated to and subjected to predominantly physical demands for long periods, may have greater difficulty adapting to the new requirements arising from the Fourth Industrial Revolution (Rescio et al., 2023; Faccio et al., 2023).

In new workplace settings, in addition to the demands of supervision, monitoring, and surveillance, professionals must work with collaborative robots. These cases require a learning and adaptation process, which can increase the duration of the activity and the number of errors, as identified in the research by Mariscal et al. (2024).

This process of adapting to new demands is independent of gender or age (Mariscal et al., 2024). In the current context, all professionals must deal with the expansion of cognitive functions, which, combined with the need for results, time pressure, and the adaptation process, can impact stress levels and, consequently, the level of performance delivered (Klumpp et al., 2024; Mariscal et al., 2024; Slazyk-sobol et al., 2021).

4.2.2 Relational analysis between variables

The research developed by Klumpp et al . (2024) revealed a statistically significant relationship between digital work and : (i) technostress , a state of anxiety, tension or suffering caused by the use of technologies; (*ii*) *time* pressure , which refers to the short time frame for executing demands, and; (iii) workload (amount of workload) of work, which refers to the set of tasks, responsibilities and attributions inherent to work practices.

A direct and statistically significant relationship was also identified between digital work and *mental* strain (Klumpp et al., 2024). This last factor requires attention, as this strain presented a statistically significant relationship with *technostress* and the incidence of burnout syndrome (Klumpp et al., 2024*)*.

The digitalization process and digital work are one of the characteristics arising from Industry 4.0. These activities require an understanding of the levels of technology to which professionals are exposed, as occurs in systematic monitoring and the level of pressure for results, which can directly influence the mental health of workers (Klumpp et al., 2024; Adriaensen; Decré; Pintelon, 2019; Wixted; O'riordan; O'sullivan, 2018).

Systematic real-time monitoring is one of the benefits arising from the Fourth Industrial Revolution. It demands attention, as it can generate tension and mental stress due to two main factors: (i) the time pressure created to achieve expected results and specific goals; and (ii) the natural induction of competition among workers as they see each other's performances (Kim; Kang; Park, 2022).

The research developed by *Klumpp* et al. (2024) also identified an inverse and statistically significant relationship between mental strain *and work* performance *,* which was assessed based on five variables: vigor, dedication, absorption capacity, satisfaction and positivity.

Finally, a directly inverse relationship is identified between mental stress and emotional factors related to well-being, such as satisfaction, engagement, positivity, and dedication at work. This relationship stems from advanced automation and continuous monitoring of worker performance, leading to problems such as high levels of absenteeism, decreased productivity, and emotional exhaustion (Hijry et al., 2024; Faccio et al., 2023; Klumpp et al., 2024).

4.2.3 Analysis of technologies used to identify mental stress

To identify physiological signs that indicate states of mental stress, advances in technological development are observed, so that tools and methods become increasingly more precise and less invasive, avoiding the induction of stress simply by using the equipment (Rescio et al., 2023; Mariscal et al., 2024).

The development of a prototype wearable equipment was identified, capable of collecting data on Electrodermal Activity (EDA) and variation in heart rate (HR), both considered accurate indicators of mental stress, and which also use environmental parameters to assist in this assessment (Rescio et al., 2023; Blandino, 2023).

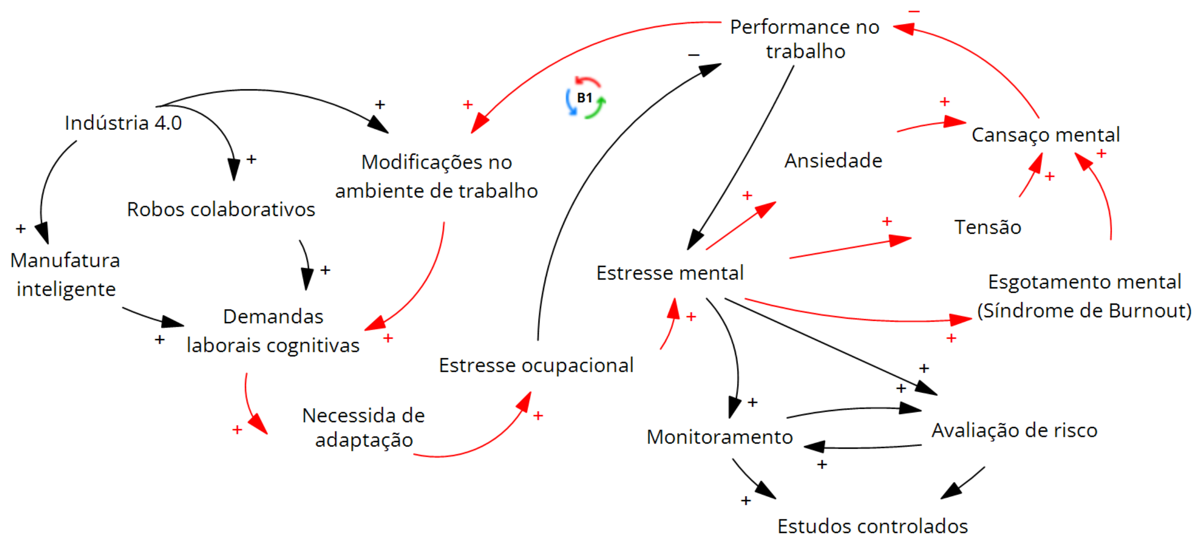
Eye- tracker equipment was also observed, which is a technological tool used to analyze pupillary dilation and assess mental stress (Rescio et al., 2023; Mariscal et al., 2024).

Technological advancement and the increased applicability of the Internet of Things (IoT) contribute to improving the identification of signs indicating mental stress and contribute to monitoring and intervention, in the most worrying cases, being carried out quickly and accurately, thus demonstrating the importance of technology applied to the daily lives of workers, in a less invasive way (Blandino , 2023; Hijry et al., 2024).

4.3. Causal Link Diagram (DEC)

Based on the relationships found in the network analysis generated by the VOSviewer software and the relationships established in the Content Analysis, a *framework was constructed* that synthesizes these relationships using the Causal Link Diagram (CLD). This diagram identifies relationships based on whether a given factor contributes to the increase or decrease of related factors. The representation is shown in Figure 8.

Figure 8: Conceptual *framework* that summarizes the relationships found



Source: Own authorship (2025)

Among the relationships identified in the *framework* , the following are mentioned:

- Industry 4.0, based on processes such as digitalization and smart manufacturing, has promoted changes in work environments that have transformed labor demands and increased cognitive demands, such as: greater volume of information, greater interaction with devices, and the need for faster decision-making.
- The use of collaborative robots has increased productivity in workplaces and primarily reduced physical demands. However, this has also led to new cognitive demands arising from human-machine interaction;
- The new demands arising from Industry 4.0, highlighting greater cognitive loads (e.g., interaction with a greater volume of information, greater interaction with devices and the need for faster decision-making) and the need for adaptation, have increased the levels of occupational stress and, consequently, mental stress among workers.
- The new cognitive demands required an adaptation process, as they were previously placed in a work environment that was predominantly physically demanding. Consequently, the greater the need for adaptation, the more difficult the learning process, and consequently, the higher the workers' stress levels.
- The incidence of stress showed a direct relationship with tension, anxiety and mental exhaustion associated with burnout syndrome.

The graphical structure created allowed us to identify a closed cause-and-effect cycle (loop B1), called "Influence of Cognitive Demands." It was observed that the changes resulting from Industry 4.0 have increased the cognitive demands of workers. This increase, resulting from new work demands and the constant need to adapt to a new context, has made professionals more susceptible to occupational stress.

Increased stress levels intensified mental strain while performing tasks, and anxiety and mental exhaustion became more frequent. These factors, consequently, increased mental demands and, most importantly, mental fatigue throughout the workday.

This new context can negatively impact employee performance, such as increased task completion time and increased errors. This decline in performance, coupled with the increasingly rapid adoption of robots and technological infrastructure, heightens concerns about job security, also increasing workers' stress and anxiety levels.

5. Discussion

Digital work significantly influences the increase in mental stress (Klumpp et al., 2024). One of the characteristics of this type of activity, connected with high levels of mental stress, is the workload, due to the increase in cognitive functions and the number of tasks performed simultaneously (Klumpp et al., 2024; Faccio et al., 2023).

There is also an impact on the number of human errors resulting from work overload, especially when the workload exceeds the professional's operational capacity (Wixted; O'riordan; O'sullivan, 2018). This occurs when a worker has to deal with more functions in a reduced time or when they need to deal with a large amount of information, characteristics provided by the advancement of digital work (Mital; Pennathur, 2004; Wixted; O'riordan; O'sullivan, 2018; Klumpp et al., 2024).

Other sources of error arise from interaction and stress induced by the relationship with collaborative robots. A study by Mariscal et al. (2024) found that errors in human-robot interactions increased 38%. Waiting processes in this relationship, whether between the robot and the collaborator or vice versa, increase the time required to complete the activity, impact time pressure, reduce productivity, and increase the risk of induced stress (Mariscal et al., 2024).

New forms of interaction between workers and machines, combined with technological challenges and the need for adaptation, have generated new sources of stress. The main factors include:

1. The intensification of work promoted by information and communication technologies;
2. The overload of data provided by intelligent machines, resulting in increasing volumes of *big data* ;
3. Increasing qualification requirements to manage large amounts of information;
4. Changes in the organization of work, with increasingly broader scopes of action.

These elements, when combined, tend to increase occupational stress levels, favoring the emergence of work-related mental disorders and reducing job satisfaction. As a result, factories suffer losses, such as increased absenteeism and decreased worker productivity (Angerer et al., 2018; Wixted , O'Riordan & O'Sullivan , 2018; Blandino , 2023).

Furthermore, new work modalities, with the integration of digital technologies for systematic and real-time monitoring, constitute a major source of stress for workers (Kim; Kang; Park, 2022). Key performance indicators (KPIs) are delivered in real time through new interconnected machines and technologies, unintentionally creating time pressure, inducing tension and stress resulting from workers' concerns about performance.

It is also important to highlight the impacts that mental exhaustion (Burnout Syndrome) can have on professionals, such as emotional, cognitive, and physical impairments, affecting mental health and professional performance. Concurrently, it can also result in exhaustion, demotivation, low productivity, and difficulties in interpersonal relationships in the workplace (Marques; Carlotto , 2024; Gil-Monte, 2010).

This scenario was highlighted by the DEC, which showed that the increased cognitive demands on workers, resulting from new work requirements and the constant need to adapt to the Industry 4.0 context, made professionals more susceptible to occupational stress, mental exhaustion, and psychological risks. This scenario reinforces a direct impact on health and, consequently, professional performance. Therefore, the use of mitigating strategies is required, such as training focused on adaptation and redesign of human-machine interfaces.

6. Conclusions

The new technologies implemented in Industry 4.0 can bring benefits in reducing the physical workload of workers in manufacturing processes. However, they present the emergence of new sources of mental workload due to the increase in functions performed by each operator, the process of adapting to new demands, and the continuous interaction with technological devices, such as collaborative robots.

The accumulation of functions and tasks increasingly demands the cognitive and mental capacity of workers, which may exceed the working capacity of operators and lead to the emergence or increase of occupational mental stress.

Empirical studies based on questionnaires and interviews are used to assess mental stress, and these studies have relatively low reliability. Alternatively, the development of equipment for measuring and monitoring physiological signals, such as heart rate, blood pressure, electrodermal activity, and pupillary dilation tracking, has been spreading within the academic community as more reliable parameters, despite these being applied mostly in controlled environments.

Therefore, Industry 4.0 factors, such as factory automation, smart manufacturing, and the implementation of interconnected and constantly monitored machines, are directly related to mental stress and occupational stress due to the increased demand on cognitive functions, mental workload, the demand for high productivity, and the constant evaluation of workers.

Therefore, as the Industry 4.0 production model demands greater performance and productivity, which are negatively influenced by the implementation of new machines and new production systems, the mental load required affects personal emotional factors due to mental exhaustion resulting from the new work demand, affecting the feeling of satisfaction, dedication and positivity in relation to work, leading to the development of pathologies such as burnout syndrome, anxiety and depression.

It can be concluded, therefore, that Industry 4.0 has increased cognitive demands, requiring professionals to adapt to the new work environment. As a result, professionals have become more susceptible to occupational stress, mental exhaustion, and psychological risks. This demonstrates a direct impact on health and, consequently, professional performance.

Taking into account the limitations of the research, such as the fact that it is a subject more recently introduced in the academic community, in addition to there being few studies related to the topic and several of the results being expressed through empirical validations and in controlled environments and studies, future studies are therefore recommended.

For future research, it is suggested that the various sources of stress in manufacturing systems be evaluated in a real situation, in a smart factory in Brazil, with the aim of identifying other factors that induce stress at work in addition to those already discussed. In this way, the processes of prediction and adequate treatment of stress can be better developed and directed, considering that the theoretical basis of this literature review did not identify studies carried out in Latin American countries, which may compromise the effectiveness of applying the results in real contexts in Brazil, given the existing cultural and social differences.

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