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MACROERGONOMICS: AN ANALYSIS OF THE DEFINITION BASED ON THE LITERATURE

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Abstract: The text addresses the evolution of the concept of ergonomics, from its initial definition in 2000 by the International Ergonomics Association (IEA), to the development of macroergonomics. Initially, ergonomics was subdivided into three domains: physical, cognitive and organizational. However, in 2020, the IEA revised this approach, emphasizing that ergonomics does not have specific domains, but rather a holistic approach that considers several factors, such as physical, cognitive, organizational and socio-technical.

The research carried out involved bibliographic review, article analysis and classification of macroergonomics concepts into three constructs: approach, basis or consideration, and objectives and results. The results revealed that macroergonomics addresses the socio-technical system as a whole, considering organizational, social, cultural aspects, among others. Its objectives include the design and optimization of organizations and work systems, aiming to improve organizational performance and human well-being.

Furthermore, the research highlights important authors and publications in the area, highlighting the evolution of the concept over time. It is concluded that macroergonomics is an approach to ergonomics that seeks to optimize the performance of the system as a whole, integrating human and organizational aspects. The text also pays tribute to the contribution of Lia B. de M. Guimarães to the development of the research.

Keywords: Macroergonomics; Revision; Definition.

Introduction

In August 2000, the International Ergonomics Association – IEA, defined Ergonomics (or Human Factors) as the scientific discipline dedicated to understanding the interactions between human beings and other elements of a system, and the profession that applies theories, principles, data, and methods to projects to optimize human well-being and overall system performance (IEA, 2020). This same definition was adopted by the Brazilian Ergonomics Association (ABERGO, 2020). Ergonomics seeks, based on the analysis of physical, cognitive and organizational factors, to reduce the harmful consequences of work on the worker and increase the satisfaction and health of those involved in the work system (IIDA and GUIMARÃES, 2016).

Still in 2000, the IEA and ABERGO proposed that Ergonomics operates in three areas of specialization: Physical Ergonomics, which studies characteristics linked to anatomy, physiology, anthropometry and biomechanics linked to physical activities; Cognitive Ergonomics, focusing on mental work processes, and Organizational Ergonomics, which translates into the optimization of socio-technical systems, including the organizational system, policies and processes (IEA, 2020). However, focusing on just one area of specialization is not always capable of generating improvements in performance and well-being. An example of this fact is the research by Galvão et al. (2012), in which the approach focused on physical and cognitive ergonomics were unable to improve health or performance indicators.

In March 2020, the IEA no longer considered these three domains of specialization and highlighted that Ergonomics does not have specific domains, as the issues that are addressed are systemic. This classification, therefore, should not be used separately in practical applications. The approach must be holistic, considering physical, cognitive, socio-technical, organizational, environmental factors, among others (IEA, 2020). This new understanding is in line with the more comprehensive approach to ergonomics, or macroergonomics, which considers cultural, organizational issues, work processes, among other factors, with a focus on the production system as a whole (IIDA and GUIMARÃES, 2016).

The objective of macroergonomics is to optimize the functioning of the entire system, by analyzing the interfaces between the human being and: organization, technology, environment and people (GUIMARÃES, 2010). Authors such as Hendrick (1996; 2003), Guimarães (2012), Bitencourt (2003), Kleiner (2008) and Derenevich (2017) argue that, with

macroergonomics, an increase in organizational performance is achieved, by contributing directly and indirect way of reducing waste.

Despite the contribution that macroergonomics can offer, not only to people's well-being, but also to system performance, the approach is little used and understood, with different definitions of macroergonomics being found. Therefore, this research aimed to review the definitions of macroergonomics found in the literature to better understand the concept and elaborate its aspects within the following constructs: A) Approach, B) Base or Consideration and C) Objectives and Results.

To this end, this research was structured in the following steps: 1) Review of published articles that mention macroergonomics; 2) Cutting out the definition of macroergonomics and framing it in the constructs; 3) Qualiquantitative analysis of the definitions found; and 4) Establish a definition of what macroergonomics is, based on the study.

Development

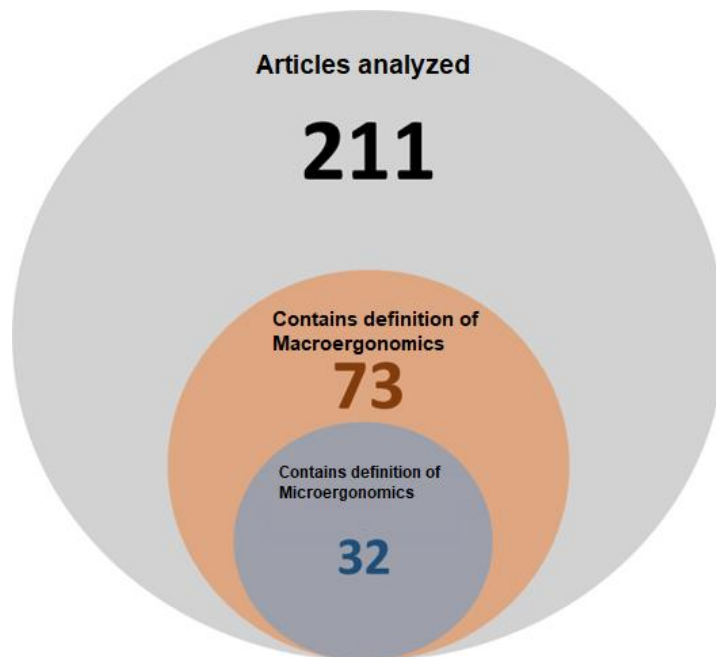
As described in the methodological procedures, in step 1, published articles that mention macroergonomics were reviewed. The search was carried out between December 2018 and March 2019, and updated in January 2020, on the journal platform of the Coordination for the Improvement of Higher Education Personnel (CAPES) as the primary source.

As the platform had more than 45 thousand full-text titles, from 130 reference bases, articles in English and peer-reviewed articles were selected initially. Then, duplicate articles and those that had no relation to the topic were excluded. Relevant references that appeared in the initial search and articles from the authors' personal library, which met the initial search criteria, were also inserted.

For the search term strategy, the end of all forms of writing the term “macroergonomics” in English was changed, these being: “macroergonomics”, “macro ergonomics” and “macro-ergonomics” to “macroergon*”, “macro ergon*” and “macro-ergon*”. A result of 539 articles was obtained. The filters were then applied: articles, in English, without time restrictions and peer-reviewed articles, which caused the number of results to drop to 190. Of these, three were duplicates.

With the individual analysis of the articles, a further 18 publications that were not articles or were not in English and articles that were not related to the topic were removed. In addition, 42 articles were added to the research, based on references in the articles visited and from the authors' personal library. Thus, the search resulted in a scope with 211 articles, of which only 73 contained a partial or full definition of macroergonomics and 32 contained a partial or full definition of microergonomics, in the perception of Derenevich (2020) (Figure 1).

Figure 1 - Representation of the total number of articles studied



Source: Derenevich, 2020.

A survey of the concepts and characteristics of what is understood by macroergonomics was carried out, which aspects the macroergonomic approach should contain, what is the relationship with organizational ergonomics and who are the reference authors for each definition. To this end, the Adobe Reader® search tool was used to search for the terms “macro” and “micro” in the texts and articles that had image format were read in full to find the terms. Consequently, the sections described by the authors as macroergonomics were identified.

Then, a descriptive analysis was carried out with data from the total scope, of 211 articles, containing publications by year, main authors, main places of publication, etc. From the tabulation for the 73 that contained the definition of ergonomics, the excerpts that contained characteristics of macroergonomics were recorded, and the authors referenced in the

definitions. Then, for step 2, the excerpts from the articles that defined macroergonomics were tabulated and classified into constructs.

Construct A, called “Approach”, categorizes how macroergonomics is applied and which aspects it uses to approach the system. For construct B, called “Base or Consideration”, what is supported by the theory and what refers to macroergonomics is classified. For construct C, called “Objectives and Results”, what is expected to be achieved from the macroergonomic approach is characterized. In short, we sought to answer “What?”, “How?” and for what?”.

In stage 3, a qualitative and quantitative analysis of the definitions found was carried out, based on: tabulation of results in relation to the total number of articles published by authors and co-authors, and the total number of their citations; outline of a timeline with macroergonomics milestones and grouping of similar definitions, from the point of view of Derenevich (2020). In stage 4, a definition of what macroergonomics is in each construct was established, based on the results of the previous stages.

Results and discussions

The first article with the name “macroergonomics” appears in 1985, written by Hal Hendrick, who understands it as the fourth phase of the historical evolution of ergonomics, and the subdiscipline that deals with the technology of the human-organization interface and is a form of increase the overall performance of the system (HENDRICK, 1985).

Since then, macroergonomics has undergone changes in its understanding and application. In this context, and based on the scope of the research, the authors of the articles were tabulated in rankings according to the total number of publications they have within their own scope, as seen in table 1. Table 2 presents the ranking considering solely the main author.

Table 1 - Publication ranking by authors and co-authors

Author and Co-author	Total Articles Published
CARAYON, P	12
AZADEH, A.	9
KUMAR, R.	6
HENDRICK, Hal W.	5
KLEINER, B. M.	5
SMITH, Michael J.	5
GENAIDY, A.	4
GUIMARÃES, L. B. de M.	4
KARWOWSKI, W.	4
AMELLA, T.K.	3

BERGSTRÖM, Johan	3
CLEGG, C. W.	3
GAEINI, Z.	3
HOONAKKER, P. L. T.	3
REALYVÁSQUEZ, Arturo	3
SAURIN, T. A.	3
WILSON, John R.	3

Source: Derenevich, 2020.

Tabela 2 - Ranking de publicação - autor principal

Main author	Total Articles Published
AZADEH, A.	7
CARAYON, P.	7
HENDRICK, Hal W.	4
REALYVÁSQUEZ, A.	3
AMELLA, T.K.	2
BERGSTRÖM, Johan	2
DRURY, Colin G.	2
GENAIDY, Ash	2
HIGNETT, S.	2
KLEINER, Brian M.	2
TAVEIRA, A. D.	2

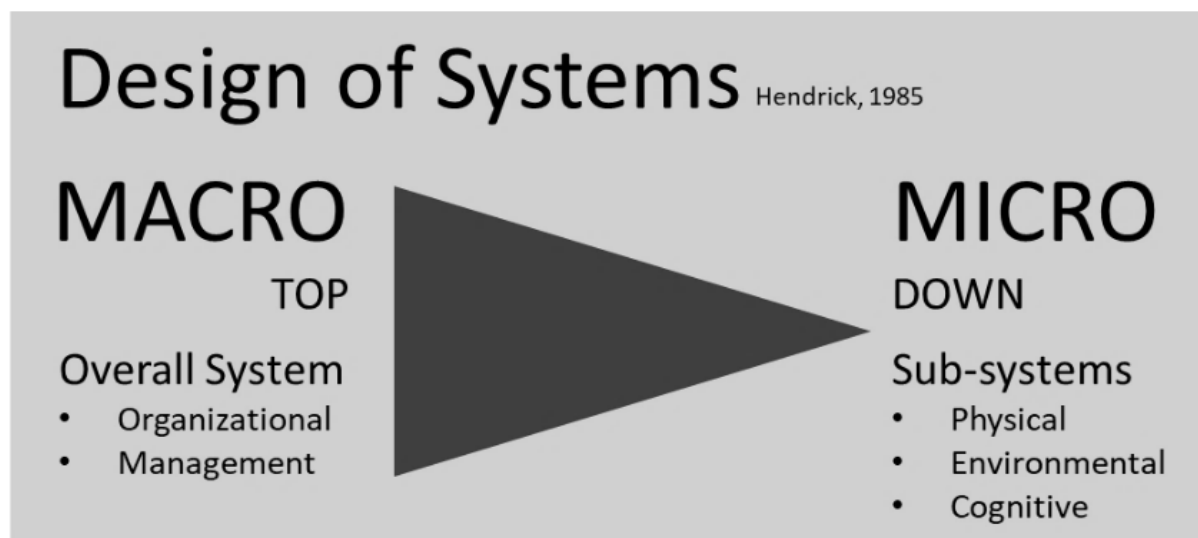
Source: Derenevich, 2020.

It should be noted that, although HENDRICK, H. is known as the father of Ergonomics, it is the authors CARAYON, P., AZADEH, A. and KUMAR, R. who stood out most in the ranking of authors and co-authors, with 12 , 9 and 6 articles published in total, respectively – which is understandable given the death of Hal Hendrick in 2011. It is worth highlighting that, in Brazil, the only author in the ranking is GUIMARÃES, L. B. de M., being the co-author of four articles. In the ranking of main authors, HENDRICK, H. continues behind CARAYON, P. and AZADEH, A. It is important to highlight that researchers such as HENDRICK, H. and GUIMARÃES, L. B. de M. already used the macro approach in their ergonomics work, without yet having a concrete definition.

As Hendrick's contribution was notable, as he brought the term macroergonomy, a visual representation of its definition was created (Figure 2). According to the author, this subdiscipline is responsible for dealing with human-organization interface technologies, analyzing from the “top” to the “down”, that is, from the entire system to its subsystems, while microergonomics is not as comprehensive. As Derenevich (2020) mentions in his work:

“Macroergonomics is differentiated by its macro character, by approaching the organization and the system as a whole, in a “systematic and progressive” way. According to Hendrick (2002), macroergonomics takes two years to be fully incorporated into an organization. This occurs precisely because of this characteristic, as it is necessary to resolve issues step by step, but gradually and constantly. On the other hand, its results appear before this date, taking between 6 and 24 months to notice improvements in the system (HENDRICK, 2008).”

Figure 2 - Representation of the definition of macroergonomics in Hendrick's view

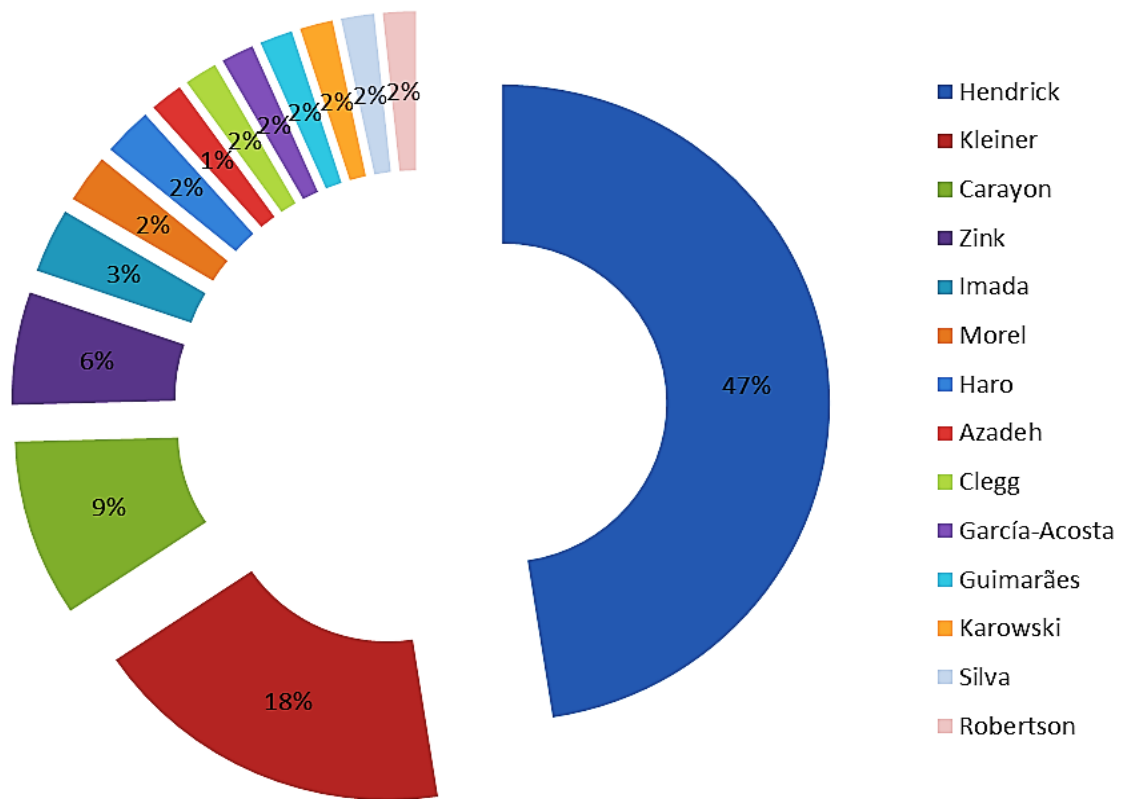


Source: Derenevich, 2020.

Furthermore, the 73 articles that contained some definition of macroergonomics were analyzed and read in full. Then, this data was tabulated and categorized with the respective authors and the number of observations from the references cited for the definition of ergonomics. From this, a visual representation of the grouping of citations was made, as can be seen in figure 3.

It is clear that Hendrick stands out as, in addition to being a pioneer, a reference in macroergonomics, as well as other authors in the sequence: Kleiner, Carayon, Zink, Imada, among others. The most cited definition of macroergonomics is published by Hendrick and Kleiner (2001), with 62 references, followed by publications by Hendrick (1995, 1997, 2002) and Carayon (2006).

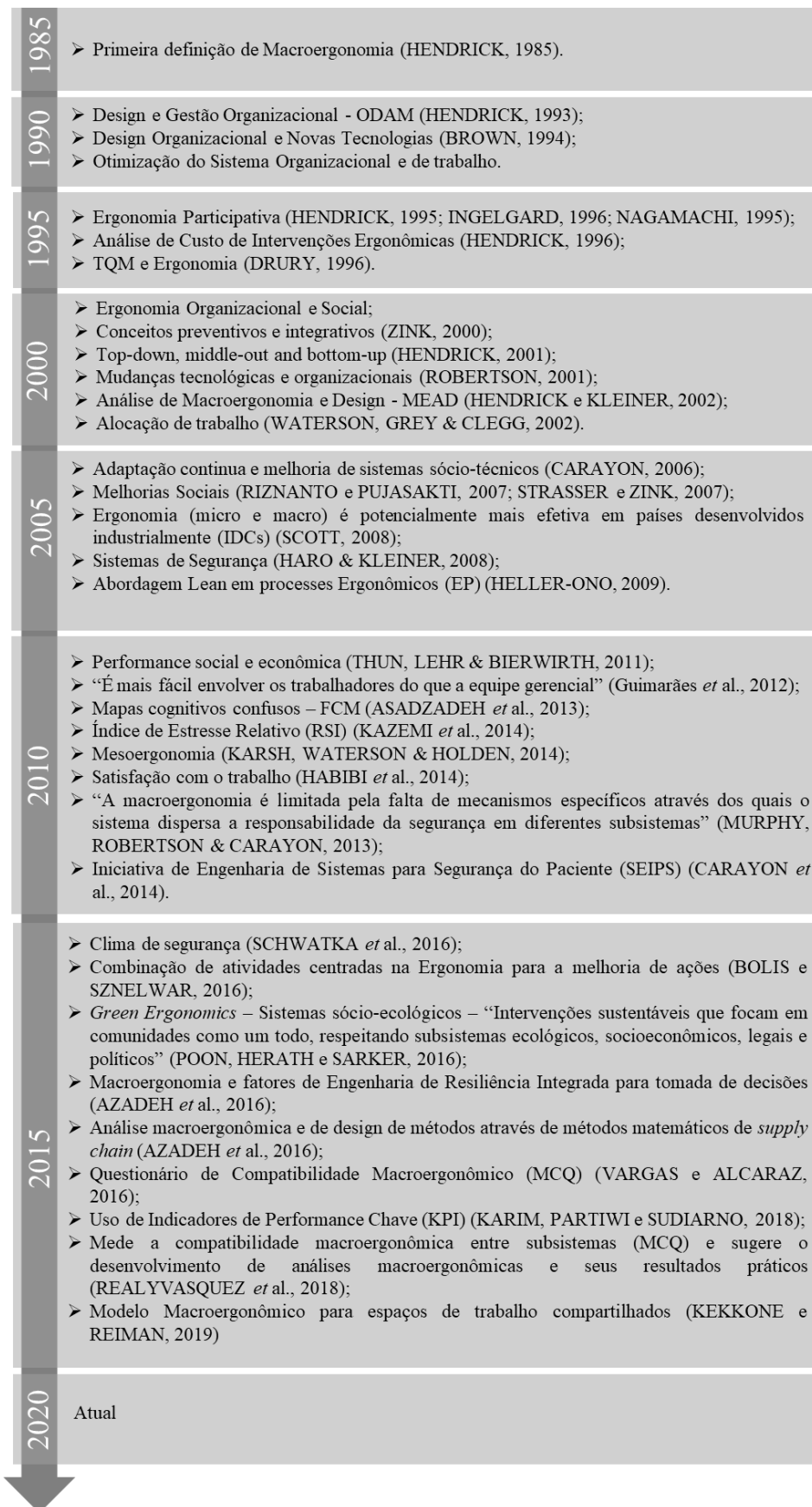
Figure 3- Main Macroergonomics References



Source: Derenevich, 2020.

A timeline was then created that presents the milestones, separated every five years. This timeline, presented in figure 4, also highlights the appearance of terms within the history of macroergonomics, understood as important in its evolution process. It is worth mentioning that the development of this timeline was not limited to articles alone, as it was based on several relevant publications.

Figure 4 – Macroergonomics milestones according to the authors



Source: The authors (2022).

It is noted that, since the first definition of macroergonomics given by Hendrick (1985), the volume of contributions to this area has gradually increased. With this, essential terms emerged for the construction of its definition. This evolution also indicates a need to define the characteristics of macroergonomics. In this context, and following the research steps, these aspects were therefore classified into the constructs Approach, Base or consideration and Results.

A) The approach

The most cited characteristics and aspects were tabulated, as shown in table 3. In total, 12 approaches stood out and were considered as those that most represent the aspects that macroergonomics uses to approach the system. Of these, “Top-down”, proposed by Hendrick, was the most cited characteristic, followed by “Participatory Ergonomics”, proposed by Brown.

Table 3 - Macroergonomics characteristics

Approach	Total
Top-Down	19
Participatory Ergonomics	13
Organizational scale	4
Bottom-up	4
Multidimensional and interdisciplinary perspective	4
Human-system interface	2
Middle-out	2
Intervention and Ergonomic Work Analysis	2
Organizational Design and System Technologies	2
Systematic and progressive	1
Qualiquantitative	1
Structure, methods and processes of the Sociotechnical System	1
Analysis and Assessment of work systems	1

Source: Derenevich, 2020.

B) Basis or Consideration

The Base or consideration construct reveals which are the “pillars” that support the theory from a macro approach, as well as what is the minimum that needs to be evaluated in this case. Table 4 presents the tabulation of the definitions of this construct.

It is observed that more than half of the scope of articles (58.9%) consider the socio-technical system as a basis for macroergonomics. It should also be noted that there are different

interpretations for sociotechnical systems, some of which are composed of human beings, organizations, environments and machines; and in others by the personal, technological and external environment subsystems. Consideration of the system as a whole and the organization in an integral way are also frequently observed in the literature.

Based on these results, macroergonomics reveals itself as a way of integrating aspects of culture and the external part of the organization with internal issues of performance and performance.

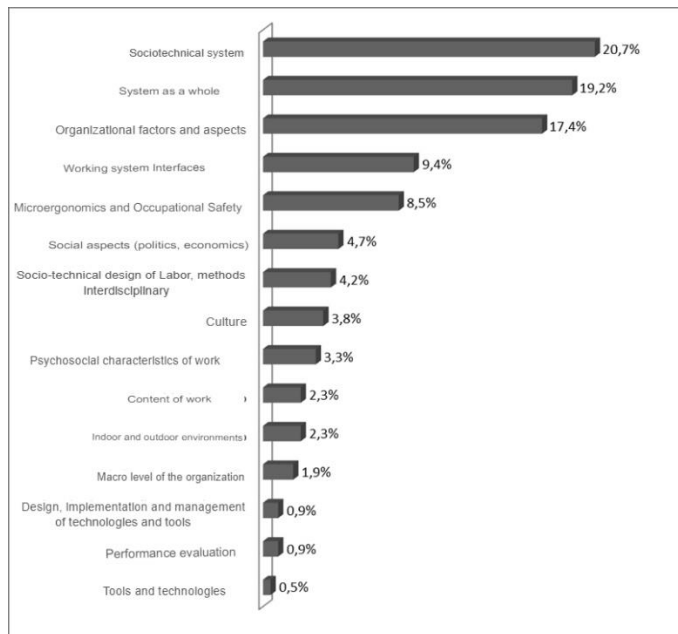
Table 4 - Definition of Base or Considerations for macroergonomics

Basis or Considerations	Total
Sociotechnical system (human, organization, environment and machines/personal, technological and external environment)	44
System as a whole (individual, tasks, technologies and tools, environment and organizational conditions)	41
Organizational factors and aspects (tasks and work control, organizational climate, leadership style, processes and structure, feedback)	37
Work system interfaces (human-work interaction, machine, software, hardware, technology, organization)	20
Microergonomics and Occupational Safety (physical characteristics, health and well-being)	18
Social aspects (politics, economy)	10
Sociotechnical work design, interdisciplinary methods	9
Culture	8
Psychosocial characteristics of work	7
Internal and external environments	5
Job content (variety, challenges, cognitive demand, achievement, overload)	5
Macro level of the organization	4
Performance evaluation	2
Design, implementation and management of technologies and tools	2
Tools and technologies	1

Source: Derenevich, 2020.

Next, figure 5 shows the percentage representation of the definitions found previously. It is noted, then, that the socio-technical system, vision of the system as a whole and organizational factors and aspects together represent approximately half of all aspects cited as a basis for macroergonomics. It is worth mentioning that, despite being important, performance evaluation is one of the least reported as necessary in macroergonomics. Furthermore, none of the publications studied cited most or all of the terms from the Base set or considerations for macroergonomics.

Figure 5 - Percentage representation of the bases or considerations in Macroergonomics



Source: The authors, 2022.

C) Objectives and Results

The objectives and expected results of macroergonomic interventions fall into two categories: human-oriented and system-oriented. However, although macroergonomics is seen and defined as providing system performance improvements, authors do not always discuss these results. Therefore, this construct was the one with the lowest number of citations when compared to the others.

Regarding objectives oriented towards human beings, it is noted that what is most mentioned as the main benefit is the worker's better feeling of safety, health and quality of life (Table 5).

Table 5 - Objectives and results of macroergonomics for humans

Objectives and Results for the Human Being	Total
Improves worker safety, health and quality of life	7
Optimizes Human Performance (effective learning environment)	6
Improves employee training and satisfaction and reduces absenteeism	4
Reduces musculoskeletal disorders	3
Reduces human costs (injuries and illnesses)	1
Encourages investment in human capital	1

Source: Derenevich, 2020.

As for system-oriented objectives, it was noticed that the most cited is the Work Organizations and Systems Project, which is the structuring of the way in which the system interfaces talk to each other (Table 6). It is noteworthy that the authors cited 3.2 times more results and objectives for the system than for the human being, highlighting the idea that macroergonomics is concerned with the system in general.

Table 6 - Objectives and results of macroergonomics for the system

Objectives and Results for the System	Total
Project/Design of Organizations and Work Systems	27
Optimization of Organizational Performance	13
Harmonization of the Work System at the macro and micro levels	8
Improvement of the System as a whole	7
Increases Productivity	7
Acts in the quality of Work Processes	5
Establishes positive organizational synergy	3
Maintenance and quality of equipment	3
Improves the physical environment	3
Preventative	2
Contributes to global societal issues	1
Integrator	1

Source: Derenevich, 2020.

From these results, it is possible to establish a definition of macroergonomics, as presented in table 7. In relation to its objectives, macroergonomics aims to: I) The design and optimization of organizations and work systems; II) The quality of processes, harmonization, integration and synergy of systems/organizations; III) Integration between subsystems and reduction of human costs in improving the physical and organizational environment.

Table 7 - Definition of ergonomics versus macroergonomics

	Ergonomics	Macroergonomics
Approach	-	<i>Top-down, bottom-up, middle, interdisciplinary and participatory, systematic and progressive, qualitative-quantitative.</i>
Consider	Interface between human being and system elements	Interface between socio-technical system, subsystems, internal and external environment, social, cultural, organizational characteristics, work content and safety, and microergonomics.

Results Human Being	Well-being	Increased performance, well-being, safety and quality of life, and job satisfaction
Results System	Performance	Gain in performance, harmonization and integration of the socio-technical system at a macro and micro level.

Source: Derenevich, 2020.

To achieve these objectives, it is essential to consider the socio-technical system, its interfaces, characteristics, technologies, culture, social, psychosocial and organizational aspects, the internal and external environments, microergonomics and work safety. With this, it can be said that macroergonomics views the system as a whole.

Therefore, for the authors, based on this review, it is defined that macroergonomics must address the socio-technical system, its subsystems, the internal and external environment, the social, cultural, organizational characteristics of content and work safety, with top-down analyses. down, bottom-up, middle-out, in an interdisciplinary, multidimensional, systematic, progressive, qualitative and participatory way. Therefore, this is a means to achieve human well-being and increase performance, safety, quality of life and satisfaction with work.

The importance of macroergonomics for the optimization of companies based on the improvement of the work system project is also highlighted, which integrates and harmonizes the macro level (human-organization interface) to the micro level (human-machine, human-environment interfaces). and human-software). The results of this are significant improvements in organizational performance, namely: productivity, efficiency, reliability, quality, etc., in addition to being crucial for the economic and social dimensions of sustainability.

Conclusions

Recent changes in ergonomics definitions, published by national and international associations, bring attention to the importance of the macroergonomic approach today. Given this scenario, this article aimed to review the definitions of macroergonomics and their respective classification by constructs, in addition to displaying a timeline with highlights of this evolution. As a result, 211 articles were selected from a total of 654 publications related to

the topic. The macroergonomics description terms were highlighted and used for a descriptive analysis. With the selection criteria reinforcing the presence of a macroergonomics definition, 73 articles were selected.

Some authors such as Moral and Kragt (1990), Hignet and Wilson (2004), Karsh, Waterson and Holden (2014) understand that microergonomics considers physical or cognitive issues, and macroergonomics is focused on macro-environmental issues. The definition of macroergonomics by Hendrick and Kleiner (2001) is the most cited (47% of the time), followed by Hendrick (1995, 1997, 2002) (18%) and Carayon (2006) (9%), these being the reference authors for macroergonomics.

The definitions were grouped into constructs: approach, concept or basis, and objectives and results for the human being and the system. Therefore, the main terms found to define macroergonomics were “Participatory Ergonomics” and “Top down”. Analyzing the other constructs, it is clear that this approach considers the socio-technical system, the work system as a whole and the organization of work. Furthermore, the expected results are the design of organizations and work systems and the optimization of organizational performance.

The definition established by the authors was, finally, compared with the IEA and ABERGO definition of ergonomics. Thus, it was concluded that the difference in macroergonomics as a subdiscipline of ergonomics lies in the design of the work system based on the socio-technical system, aiming to optimize the performance of the entire system. It is understood that macroergonomics is an approach to ergonomics that considers both human well-being and system performance, highlighting issues of productivity gains.

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