INTRODUCTION TO ERGONOMICS APPLIED TO INDUSTRIAL DESIGN.

INTRODUCCIÓN A LA ERGONOMÍA APLICADA AL DISEÑO INDUSTRIAL.

Prof. Arch. Franco Claudio Grossi
grossi@ieml.ru
ORCID: 0000-0002-3567-2523
Kazan Innovative University
Federación de Rusia
Autor para la correspondencia

RESUMEN

La ergonomía (o factores humanos) es la disciplina científica que se ocupa de la comprensión de las interacciones entre los seres humanos, otros elementos de un sistema y el medio ambiente. El ergonomista aplica teorías, principios, datos y métodos de todas las ciencias, con un enfoque sistémico holístico, con el fin de optimizar el diseño para el bienestar humano y el rendimiento general del sistema. Todas las naciones industrializadas hoy en día se refieren a la Ergonomía como una "herramienta" indispensable para el diseño de cualquier producto y se han promulgado más de 100 normas ergonómicas ISO-EN que deben cumplir cualquier producto y proceso de producción. El objetivo de la Ergonomía es identificar un diseño orientado al usuario y, para ello, proporcionar al diseñador pautas para proceder en el cumplimiento de las limitaciones impuestas por las características físicas y psicofisiológicas del ser humano.

ABSTRACT

Ergonomics (or Human Factors) is the scientific discipline that deals with the understanding of the interactions between humans, other elements of a system and the environment. The ergonomist applies theories, principles, data and methods of all sciences, with a holistic systemic approach, in order to optimize the design for human well-being and overall system performance. All industrialized nations today refer to Ergonomics as an indispensable "tool" for the design of any product and more than 100 ISO-EN ergonomic standards have been promulgated to which any product and production process must comply. The purpose of Ergonomics is to identify a user-oriented design and, to this end, to provide the designer with guidelines to proceed in compliance with the constraints imposed by the physical and psychophysiological characteristics of the human being.

Palabras claves:

Diseño Industrial,
Ergonomía,
Factores humanos,
Diseño centrado en el usuario.

Keywords:

Industrial Design,
Ergonomics,
Human Factors,
User-Centered Design.

Fecha Recibido: 15 / 02 / 2022
Fecha Aceptación: 21 / 03 / 2022
Fecha Publicación: 12 / 07 / 2022

PREMISE

This contribution is merely a preliminary treatment and aims to provide the basic elements for a subsequent study of the discipline of Ergonomics. In particular, from a practical point of view, we want to underline the fact that, through the use of methodologies inherent to ergonomic design, we are now able both to anticipate the needs of the user and those relating to the innovation of the process and of the product and both to combine the designer's needs for freedom of expression with those imposed by standards and functional and production constraints.

ETYMOLOGY, BIRTH AND DEFINITION OF ERGONOMICS

The noun Ergonomics comes from the ancient Greek "*ἔργον*"(ergon: work, work, task) and "*νόμος*" (nomos: use, custom, custom, custom, law, rule, lexical cognate of: "*νέμω*" (nemo: to govern, way of administering, way of distributing orderly). So, how to "govern" the work activities. Ergonomics was created to study and enforce a series of rules in the design that protect the life of the worker and increase the efficiency and reliability of man-machine systems in matters of health and well-being. The current objective is to contribute to the design of objects, services, living and working environments, so that they respect human limits and enhance their operational capabilities. Ergonomics is nourished by scientific and technological acquisitions that allow to improve the quality of living conditions, in all daily activities. But let's try to illustrate the path that led, in 1949, to the birth of ergonomics, as a scientific discipline. The Encyclopedia Britannica states that *"diseases directly related to occupations were recognized by early Egyptian and Roman physicians. Modern occupational medicine may be said to have started with Bernardino Ramazzini"*. In 1700, in fact, Bernardino Ramazzini, professor of medicine at the University of Modena and Padua was the first to deal with problems relating to work and published the text "De Morbis Artificum Diatriba" (dissertation on the diseases of artisans, published in 1713), in which he analyzed and associated about forty diseases with the work duties, especially artisanal ones, of that period. In 1774 William Buchan took care of the uncomfortable job position of craftsmen and tailors and, in 1830, Charles Turner founded Occupational Medicine in England. In 1949, in order to analyze the problems that arose in adapting the equipment and operating speeds of war machines and related industries to human possibilities, K.F.H. Murrell (1908-1984) gathered a group of scholars at Oxford and with them founded the Ergonomics Research Society. Murrell's new theory referred to the machine as a work tool and to man as the user of this medium, in the context of a man-machine-environment system. Each work organization system is therefore made up of a human operator, the means and methods he possesses and uses, all in the environment in which he operates. "Fitting the job to the worker" is the slogan adopted by the same inventor of the term "Ergonomics", K.H.F. Murrell, in total antithesis with the theory of the "Scientific organization of work" expounded in the early 1900s by Frederick Winslow Taylor and Henry Ford, who, on the other hand, wanted to "adapt man to work". Studies in this new branch of science then had a further development with the establishment, in Stockholm in 1959, of the International Association of Ergonomics (EIA).

Figure 1. The IEA logo

IEA, defines Ergonomics (or Human Factors) as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance. The terms *Ergonomics* and *Human Factors* are often used interchangeably or as a unit (e.g., human factors and ergonomics – HFE or EHF)".

A SYMBOL THAT CONNOTES ERGONOMICS

This famous representation of the ideal proportions of the human body tries to demonstrate how it can be harmoniously inscribed in the two "perfect" figures of the circle, which symbolizes Heaven, the cosmos, the divine perfection and the square, which symbolizes the Earth, the earthly world.

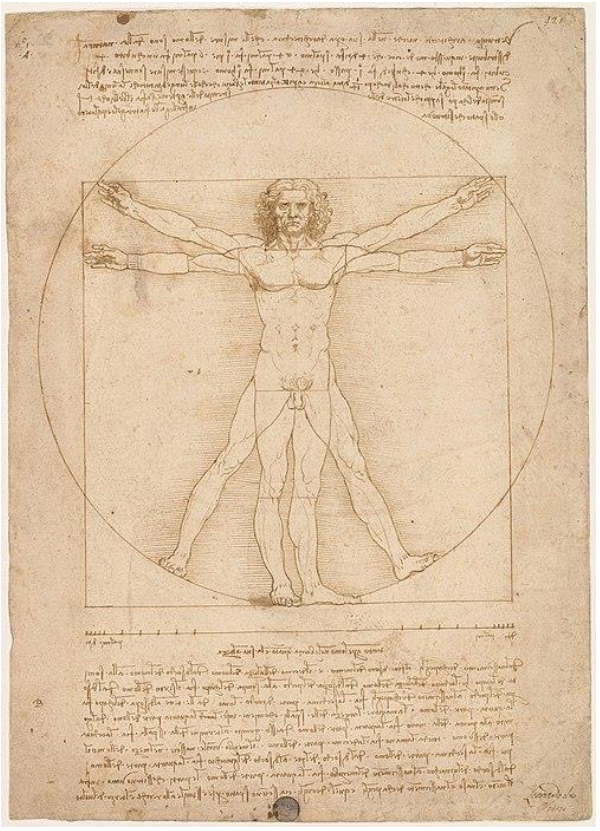

Figure 2. The drawing taken as a symbol of ergonomics

From a philosophical point of view, tracing this vision back to Platonic, Aristotelian and Neoplatonic philosophy, man is considered a "mirror of the universe". It is a pen and ink drawing on paper, measuring cm. 34.4 × 24.5, executed in 1490 by Leonardo da Vinci (1452-1519) and kept in the Cabinet of Drawings and Prints of the Galleries of the Academy of Venice. It was entitled "the Vitruvian man", or "man as the measure of all things", in which the proportions of the human body are analyzed according to the writings of the Roman architect Vitruvius (Marcus Vitruvius Pollio, ca. 80 b. C.–15 b. C.).

APPLIED ERGONOMICS

Applied Ergonomics deals, in a systemic way, with the methods and specific phases of any project, in order to lead to the anthropocentric realization of an optimal adaptation of the system "man, what man builds and the surrounding environment" to the capabilities and psychophysiological limits of the human being, through the study of specific interfaces. Moving from artisanal production, which is mainly expressed in the limited production of objects of use, to industrial production, which is instead oriented towards mass production, other problems arise. First of all, it can be said that, in order to consider an object as the result of an industrial design, in addition to having the intrinsic characteristics of safety and quality, it must possess the requisites to be "reproducible in series", to be "produced exclusively with factory systems", to "have a certain aesthetic quotient "and" not necessarily to have a practical function". Furthermore, to stand out from the "mass", an object must have an aesthetic factor, which is the operational basis for the work of a "designer", then it must be expressly conceived for mass production and therefore must be the subject of product engineering and of process. Moving from an essentially monopolistic market, such as that of craftsmanship, to that of competition, up to the global market, the canons of design must be radically revisited. First of all, it is a question of responding to the needs of safety and quality, expressly requested by consumers.

Figure 3. Maslow's pyramid

SAFETY

The concept of safety, positioned in second place in Maslow's hierarchy of needs, after that of physiological needs, is of an ancestral nature, belongs to our "reptilian" brain and has always been linked to our instinct for fear of survival. In more recent times, further issues are being developed regarding safety in the workplace, safety in communications and Information Technology, environmental and national safety and so on, continuously fueled by the development of the "risk society". Even for production and service companies, the issues relating to safety are today extremely topical and relevant, especially for national and international legislative interventions, aimed at regulating sectors that until a few years ago were left to the almost total discretion of the parties.

QUALITY

As regards Quality, the ISO (International Organization for Standardization) defines it as "The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs", in other words the set of intrinsic properties and characteristics of a product or service, that allows to satisfy declared or implicit needs, with full customer satisfaction. Furthermore, the quality of a good or a service is the perception that a customer has of it. The needs regarding Quality arose at the beginning of the 1900s, coinciding with the birth of industrial mass production, as competition and growing competitiveness led companies to place on the market products suitable to meet the needs of consumers.

Initially, the operating mechanism was identified in "testing", which was able to allow the differentiation between valid products and allow the rejection of unsuitable ones. Subsequently, control techniques were used to be carried out during the production process but without real planning of the acceptance tests. In the year 1920 the Western Electric Company created a Quality Department to resolve telephone exchange failures. The birth of total quality in the world was in direct response to a quality revolution in Japan following World War II, as major Japanese manufacturers converted from producing military goods for internal use to producing civilian goods for trade. It was therefore the Japanese who made it a pillar of their post-war industrial revival and, at the end of the 1960s, they presented their model under the name of "Company Wide Quality Control".

Today, the ISO 9000 standards are in force for the certification of the quality process.

THE ERGONOMIC APPROACH

We have seen that, in order to effectively implement the ergonomic approach, safety and quality requirements must first be met. Then we need to think about the fact that, today, the consumer wants to contribute to the project, wanting to buy a product with some characteristics expressly made for him. For this purpose, the term "prosumer" was coined, composed of the English words producer (producer) and consumer (consumer). Finally, in the global market, it is necessary to subject design to the canons of modern social media stakeholders, called "influencers", or people who are able to generate interest in something (such as a consumer product) by posting it on social media. The ergonomic approach, being essentially methodological, lends itself to being applied in a wide range of human activities.

As regards the areas of expertise of Applied Ergonomics, a first subdivision into three typologies can be attempted, which have

undergone an important anthropocentric evolution over time: the Biomedical Area, the Polytechnic Area and the Psychosocial and of the Organizations Area.

TYPOLOGIES AND PRINCIPLES OF ERGONOMICS

From a typological point of view, the ergonomic intervention can be classified as of conception or of correction. The ergonomic conception intervention is characterized by the fact that it is programmed in the phase prior to the project and therefore tends to minimize design errors. The ergonomic correction intervention, on the other hand, is characterized by the fact that it takes place on existing products and processes, allowing for limited and increasingly more expensive modifications than the previous one. Among the fundamental principles on which the ergonomic project is based we include: *anthropocentrism*, i.e. the man at the center of the project and the technique at his service; *global approach*, implemented through interdisciplinarity, since it makes use of the contribution of all scientific and humanistic disciplines; *group activity*, since the project is the result of the contribution of all the participants; *participation*, as sharing with all interested parties as well as with direct and indirect users is essential; *breadth of application*, because the principles of ergonomics can be extended from design, to production, to the organization of work, to the production process, up to the final product; *advantages for the company*, since the company that makes use of the contribution of Ergonomics can obtain more competitive production costs and a higher quality and innovation of the product and the production process.

AXIOM

It is important to point out that the ergonomic quality of an industrial product (or process) is an attribute concerning the use of the product and not an attribute of the product itself.

In fact, based on the principles of Ergonomics, the ergonomic quality of an industrially produced object does not exist, but instead, we can speak of the ergonomic quality of the use of an object by a well-defined set of users for a specific use and in a certain environment.

Let's take a chair for example. We can verify its ergonomic quality, based on its use, will be different related to the user (i.e., a child, an elderly person, an obese person, etc.), to its specific use (i.e., a chair for bars, dentists, cars, aircraft, etc.) and inside the environment in which it is used (i.e., a restaurant, on the beach, on the snow, etc.).

ERGONOMICS AND HUMAN LIMITS

Since ergonomic design always has anthropocentric characteristics, designers must take into account three aspects of the user before considering the creation of a product, system or service and this is what the user can do (basic skills and competences), what the user cannot do (limits) and what will the user want to do (what will he be motivated to do).

It is also necessary to be aware that man has impassable limits, which can be divided into three categories:

1. *Sensory limits*, for which it is necessary to quantify the threshold limits of the five senses, qualify and quantify the sensory deficiencies and analyze the consequent performance.

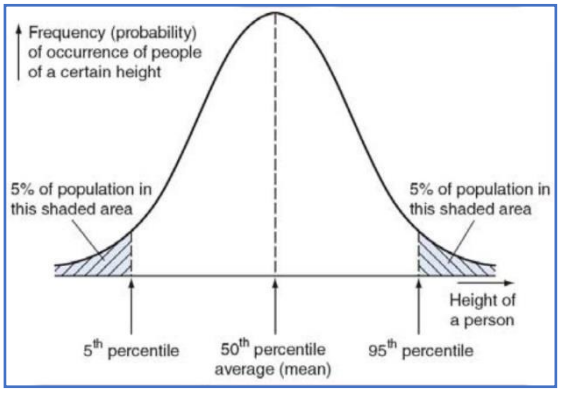

Figure 4. Data representing the height of a population of high school students in the Gaussian bell shaped curve.

2. *Physical limits*, divided into static and dynamic anthropometric ones, as well as limits of satisfaction also by disadvantaged users. As regards the anthropometric limits, it is necessary to identify the "limit users", that is all the individuals who have one or more anthropometric characteristics that can be placed at the extremes of the Gaussian curve, where, depending on the design problem, we must consider the frequency with which data relating to the measurements and physical capabilities of the human body are presented. This makes it possible to identify the thresholds below or above which it is impossible or impracticable to respond to user needs and to define the thresholds within which the solutions adopted guarantee adequate levels of accessibility and safety.

3. *Cognitive limits*, which are the most difficult to identify and are associated with cognitive processes. The most interesting from an ergonomic point of view are the threshold limits, response times and relative accuracy.

THE ERGONOMIC PROJECT

The ergonomic project uses a methodology capable of evaluating the needs of users a priori and this by "extracting" a significant sample of users, using the typical systems of inferential statistics and administering the tests to them. In fact, it would be almost impossible to administer tests to the entire universe of users. But let's get to the "toolbox" available to the ergonomist. The main evaluation method concerns the so-called "Usability" which is a quality attribute that evaluates the ease of use of the user interfaces. The ISO defines usability as " *the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*". This definition derives from ISO 9241 Part. 11: Usability Guide, to be used in its broadest sense and in all contexts. The word "usability" also refers to methods of improving ease of use during the design process. The ISO standard shows that products have inherent usability and that usability is determined by the characteristics of the user, the tasks they perform and the environment in which they are performed.

The ergonomist can then use the following tools to measure the usability of a product (or system, or service):

- *effectiveness* measures (objective), i.e., relating to the accuracy and completeness with which specific users reach the set objectives;
- *efficiency* measures (objective), concerning the number of resources committed in relation to the accuracy and completeness with which the specific users reach the set objectives;
- *satisfaction* measures (subjective), which are identified in the assessment of the comfort and acceptability of use by the user.

ERGONOMICS FOR A CIRCULAR ECONOMY

Another important aspect of Ergonomics is its close relationship with Design for Sustainability, which is expressed through the evaluation of the product life cycle. Unlike the "linear" model, in which a product is placed on the market and then eliminated at "end of life", in the circular model, on the other hand, starting from the design phase of the product, its restoration, or that of the materials of which is established, for the purpose of its re-placing on the market. In other words, the product life cycle in the circular model is traceable to the life cycle of nature and, also in this case, the end for one product represents the beginning of a new cycle for another. The ergonomic design is therefore carried out in a sustainable and circular key of the product, considering its durability, the modular and decomposable parts, the biodegradability, replacing virgin raw materials with recyclable raw materials and biomaterials, up to the management of production waste and subsequently to analysis of return flows of returns and products at the end of their life, up to providing solutions for their final management.

CONCLUSIONS:

In this brief description of Ergonomics Applied to Industrial Design, we wanted to give some indications on this design method, its peculiarities and the need for its use, also to comply with the dictates of the ISO standards. We have seen that this discipline is very complex, because it involves a systemic intervention of a holistic type in compliance with the principles of interdisciplinarity, participation and globality. Finally, to illustrate its advantages, let us consider two cases according to whether or not the principles of this discipline are used. Without the ergonomic design, the company produces a product or service and launches it on the market. There is a risk of non-acquisition by the user, as well as that of recall for manufacturing defects, safety and design quality. The ergonomic design, on the other hand, provides the right tools for testing objections and marketing issues in advance. The final result will be a document with specific prescriptions and guidelines for the designer, who at this point will have real indications on his work, with very few possibilities of making mistakes and all with a real economic saving of time and costs by the production company.

REFERENCES:

A list of 111 ISO/EN/UNI Standards regarding Ergonomics. Published by "Società Italiana di Ergonomia e Fattori Umani", Milano, Italy. http://www.societadiergonomia.it/approfondimento_norme/#norme

Alexander, D. and Rabourn, R. 2020. Applied Ergonomics. CRC Press, Boca Raton, USA. ISBN 978-03-674-5523-1.

Arellano, J. L. H., Macías A. A. M., Martínez J. A. C. and Coronado P. P. 2018. Handbook of Research on Ergonomics and Product Design. Engineering Science Reference, an imprint of IGI Global, Hershey, Usa. ISBN 978-15-225-5234-5.

Bandini Buti, L. 2001. Ergonomia e prodotto, Il Sole 24 Ore, Milano, Italy. ISBN 978-88-324-4433-X.

Grossi, F. C. 2006. L'imprenditore artigiano nella società digitale, dal modello socioeconomico post-industriale all'artigianato del "villaggio globale". CNA Cultura, Udine, Italy.

Grossi, F. C. 2022. The Distinctive Features of Artisanal Design and Industrial Design. A3manos, Revista de la Universidad Cubana de Diseño, Universidad de la Habana, Cuba, n. 16 enero - junio 2022. Pages 13-16. ISSN 2412-5105.

Harrison, J. S., Barney, J. B, Freeman ,R. E. and Phillips, R. A. 2019. The Cambridge Handbook od Stakeholder Theory, Cambridge University Press, Cambridge, U.K. ISBN 978-11-081-2349-5.

Meister, D. and Enderwick T. P. 2001. Human Factors in System Design, Development, and Testing. CRC Press, Boca Raton, USA. ISBN 978-08-058-3206-8.

Norman, D. A. 1988. The Design of Everyday Things. Basic Books, New York, USA, ISBN 978-0-465-06710-7.

Salvendy G. and Karwowski W. 2021. Handbook of Human Factors and Ergonomics, Fifth Edition. John Wiley & Sons, Inc., Hoboken, USA. ISBN 978-11-196-3608-3.

Stanton, N. A., Young M. S. and Harvey C. 2017. Guide to Methodology in Ergonomics: Designing for Human Use, Second Edition. CRC Press, Boca Raton, USA, ISBN 978-11-384-3472-1.