RBSO Revista Brasileira de Saúde Ocupacional
ISSN: 2317-6369 (online)

Essay
Dossier RBSO 50 Years

Ergonomics contribution to occupational safety

A contribuição da Ergonomia para a segurança no trabalho

Eugênio Paceli Hatem Diniz[a]
https://orcid.org/0000-0003-0789-0416

Francisco de Paula Antunes Lima[b]
https://orcid.org/0000-0003-4373-6424

Raoni Rocha Simões[c]
https://orcid.org/0000-0003-1181-0132

[a]Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho, Escritório Avançado do Estado de Minas Gerais. Belo Horizonte, MG, Brazil.
[b]Universidade Federal de Minas Gerais, Departamento de Engenharia de Produção. Belo Horizonte, MG, Brazil.
[c]Universidade Federal de Ouro Preto, Departamento de Engenharia de Produção, Administração e Economia. Ouro Preto, MG, Brazil.

Contact:
Eugênio Paceli Hatem Diniz

E-mail:
eugenio.diniz@fundacentro.gov.br

Abstract

Introduction: while high-risk processes with high accident rates challenge safety, High Reliability Organization (HRO) achieve excellent indicators. In both cases, prevention seems to have reached a limit. In the former, because it seems powerless to generate prevention; in the latter, because it has been so successful that it seems impossible to reach greater levels. **Objective:** to highlight the contribution of Ergonomics to safety in these situations, pointing out unexplored possibilities such as design Ergonomics in man-machine integration (computerized systems). **Method:** comparative analysis of findings from ergonomic studies on production systems with high accident rates and HRO. **Discussion:** analysis of the motorcycle freight drivers' activity revealed alternatives yet to be explored between unfavorable work relations and the perceived inevitability of accidents. The apparent limit of HRO can be overcome with recent advances in the analysis of situated action and cognition and by building debate spaces based on field experience. Collaborative design practices, which draw on worker experience to feed learning dynamics and technical reliability, remains a poorly explored possibility in Safety Engineering when it comes to computerized systems.

Keywords: ergonomics; motorcyclists; occupational health; collaborative project; high reliability organizations.

Resumo

Introdução: processos de alto risco com elevadas taxas de acidentes desafiam a segurança. Por outro lado, sistemas ultrasseguros conquistaram ótimos indicadores. Em ambos, a prevenção parece ter chegado a um limite – em um deles, porque parece impotente para gerar prevenção; no outro, porque foi tão bem-sucedida que parece impossível avançar. **Objetivo:** evidenciar a contribuição da Ergonomia em prol da segurança, nas situações descritas, suas possibilidades ainda por explorar, entre elas a Ergonomia de concepção na integração homem-máquina (sistemas informatizados). **Método:** análise comparativa dos achados oriundos de estudos ergonômicos em sistemas de produção com altas taxas de acidentes e sistemas ultrasseguros. **Discussão:** a análise da atividade dos motofretistas mostrou que existem alternativas de ação ainda não exploradas entre as relações de trabalho desfavoráveis e a percepção de inevitabilidade dos acidentes. Nos sistemas ultrasseguros, o aparente limite pode ser superado com os avanços recentes na análise da ação e cognição situadas e na construção de espaços de debate que permitam o retorno da experiência de campo. Em sistemas informatizados, as práticas de projeto colaborativo, que se valem da experiência dos trabalhadores para alimentar as dinâmicas de aprendizagem e a confiabilidade técnica, são possibilidades ainda pouco praticadas na Engenharia de Segurança.

Palavras-chave: ergonomia; motociclistas; saúde do trabalhador; projeto colaborativo; organizações de alta confiabilidade.

How to cite (Vancouver):
Diniz EPH, Lima FPA, Simões RR. Ergonomics contribution to occupational safety. Rev bras saúde ocup [Internet]. 2024;49:edcinq15. Available from: https://doi.org/10.1590/2317-6369/01923en2024v49edcinq15

Introduction

There is a genuine social demand for safety in production processes. Occupational safety management in companies has been predominantly reactive, without being able to learn from accidents to prevent them. Ergonomics plays a significant role in occupational safety, which motivated the production of this article. The study aims to highlight what has already been achieved and what can still be accomplished to make production systems safer and improve the design for human-machine integration.

Ergonomics and Safety are distinct fields of knowledge and action in promoting better working conditions. Nevertheless, by sharing the same object—work—they end up having a common area of action, both in practical and theoretical terms. In this overlapping zone, Ergonomics, with its specific knowledge and methods, contributes to safety in various ways, but only when human activity is present as an integral part of a sociotechnical system. Thus, within the field of Safety, Ergonomics always has something to say when human behavior is present or acts as a mediating element in the functioning of production systems.

In this article, we do not aim to create an inventory of all safety issues that can benefit from Ergonomics. This comprehensive, encyclopedic view can be found in chapters or sections of safety manuals dedicated to Ergonomics[1], or conversely, in chapters/sections of Ergonomics manuals dedicated to safety[2,3]. We adopted a different approach here: to discuss the contribution of Ergonomic Work Analysis to accident prevention in two extreme cases, both high risk. On the one hand, production systems with high accident rates (including the work of motorcycle couriers, discussed in this article, production systems in the construction industry[4], and meatpacking plants[5,6]), where prevention remains a challenge. On the other hand, there are High Reliability Organizations (HRO) where, despite the apparent dangers, the risks have been controlled to reduce accidents to rates below 10^{-6}. In HRO, such as the nuclear industry and aviation, the prevention practices and safety culture, to which Ergonomics has contributed since the post-World War II era, have been so successful that they seem to have reached a limit[7]. In both cases, prevention is at an impasse. In the first case, the implemented measures are ineffective in prevention, while in the second, prevention has been so successful that further progress seems impossible. In both cases, for different reasons, one can only accept and live with the accidents, as if nothing else could be done, essentially "naturalizing" them.

By analyzing polar situations like these, where safety is an obvious necessity, the contribution of Ergonomics can be more clearly demonstrated and simultaneously put to the test. Faced with such situations, both Safety and Ergonomics are confronted with their own limitations, emphasizing the need to expand prevention efforts.

To present the Ergonomics' contribution to safety in HRO, we discuss how activity analysis makes it possible to anticipate accidents (or learn from everyday work, in terms of Resilience Engineering[8]). Production systems with low accident rates have lost their capacity for prevention because we only learn when accidents happen. This paradox—waiting for accidents to happen and then implement prevention—can only be resolved by taking a step back and analyzing minor incidents and weak signals that manifest in everyday work situations. Hence the current interest in some more advanced branches of Safety (Safety II, Resilience, HRO…)[8-10], in understanding and learning from everyday work, an area in which activity-centered ergonomics has traditionally operated.

It may seem strange that, in a text dealing with the contribution of Ergonomics, its limitations are being discussed. However, recognizing the limits of Ergonomics opens the possibility of interdisciplinary intersections using innovative approaches. These new possibilities will be discussed in the section "Ergonomics Contribution to the Artifact Design for Human-Machine Integration (Computerized Systems)", after showing how, in the current approach, Ergonomics can contribute to the advancement of safety in these two extreme cases, motorcycle couriers (section "The Contribution of Activity Analysis to Accident Prevention in Motorcycle Couriers") and HRO (section "Analysis of Activity, Weak Signals, and HRO"). In the following section, we will delve more deeply into the common ground between Ergonomics and Occupational Safety.

Ergonomics, safety, and activity analysis

The ergonomic approach primarily focuses on the worker in a work situation or, more precisely, on the work activity that the worker carries out. The ontological approach to everyday work allows for the identification of the mediate causes of behaviors, accidents, incidents, illnesses, and work overload[11]. It is also Ergonomics' area of interest and potential to produce a body of knowledge necessary for action to transform work situations, including organizational systems and technical artifacts[12]. Within this general scope of action, various safety demands and issues arise. The contributions of Ergonomics to safety can therefore occur in three main domains:

a) Directly targeting the so-called "human factor"[13], seeking to understand how "human error" occurs, but also demonstrating how human operators are a source of reliability for technical systems.

b) In the design of material work conditions (environment, work tools, and equipment), and today, with automation and advances in artificial intelligence, promoting integration between work activity and computer systems.

c) In the realm of organization and management: understanding how organizational processes and structures affect the work of employees (including engineers and managers at various hierarchical levels); in designing organizational devices that promote Operational Experience Feedback and learning to avoid "organizational accidents"[14].

From the beginning of the approach of analyzing the work situation in its entirety, Wisner[15] already questioned the separation between unsafe conditions and human error. Subsequently, activity analysis will enable more specific contributions on the nature of human error by analyzing the dynamics of the activity in everyday situations and in the case of accidents and incidents.

The emergence of the human factor

The progressive increase in technical reliability has had the secondary effect of highlighting human errors as the predominant cause of accidents, often accounting for 80% to 90%[16] of them. In the field of psychology, since the 1980s, in parallel with the development of Ergonomic Work Analysis and the analysis of activity, human error became a major topic of study, and the "human factor" was considered the weak link in sociotechnical systems[13,17,18,19]. Based on the human factor, work psychology and ergonomics encountered the material and organizational conditions that influenced workers' activities, entering the era of "organizational accidents"[20]. At that time, sociological approaches to safety initiated a similar movement, generating the concept of "normal accidents"[21] and, later, the seminal study of the Challenger accident by Vaughan[22]. Due to space constraints, this discussion will be limited to psychology.

This demand for Safety by Psychology to address the "human factor" led to the analysis of behavior and cognitive processes detached from the situation experienced. This separation yielded systematic results regarding human failures[19,23] but at the expense of understanding the interactions between the elements of the work system, expanded by a cross-sectional, vertical, and historical approach to organizational factors[14].

Understanding accidents as a consequence of subjective processes and organizational causes undoubtedly represents an advancement in prevention. However, this dual movement has created an imbalance. Following Reason, Le Coze[18] questions whether the models and theories had gone too far, distancing themselves from proximal causes of accidents, such as maintenance and procedure failures. He proposes a multilevel analysis model that seeks to integrate aspects of the immediate situation and the broader organization (social, economic, and political) and the levels of individual and collective activity while taking cognitive processes into account. To achieve this, the analysis must be capable of describing what happened at the exact moment when the errors, incidents, and accidents occurred. This is the point at which Ergonomic Work Analysis, especially situated activity analysis, enables progress by providing an integrated description of how the organizational context, material conditions, and work activity intertwine.

The contribution of activity analysis to accident prevention with motorcycle couriers

Usually, discussions about accidents involving motorcycle couriers or professional motorcyclists—workers who provide services using motorcycles—seldom go beyond common-sense to prevent these events and often fail to explore the potential implications of work relationships and organization on the behavior of this category. Proposals for prevention[24] typically involve raising awareness of risks and the value of life, providing training by legal experts, and enforcing penalties.

By ignoring oppressive management and precarious working conditions, these recommendations for accident prevention in this sector seem to be nothing more than fables or perversities, since it is impossible for workers to abide by traffic rules[24] all the time. An analysis of the activities of motorcycle couriers in the dispatch process of companies and on public roads revealed how much the organization and work relationships impact on the conduct of these workers[24].

To illustrate the situation, **Chart 1** summarizes the contributions of different perspectives on the work of this category and shows that Ergonomics can provide proposals for actions that can be implemented within companies and beyond, in the regulation of a given professional activity, even in extreme and seemingly unsolvable situations. The analysis of the motorcycle couriers' activities confirms that the key to safety is not isolated normative power, but rather that norms and procedures do not dissociate or hinder workers' ability to manage the activities they carry out, individually or collectively[25]. As an example of an action that goes beyond normative limits, the autonomy that some motorcycle couriers had at certain times to reorganize their tasks allowed them to more effectively explore information from the technical and human environment, thus reducing the complexity[26] of the vehicle traffic system.

Chart 1 The contributions of different views on the work of motorcycle couriers

The external perspective on work	The Ergonomics perspective	Contributions of Ergonomics to production, and to worker safety and health
Obey traffic laws. Do not ride in between lanes. Pay attention to traffic. Theoretical and practical course, held on a course with cones in a yard. Accreditation. Implement and increase penalties. New, well-maintained vehicles.	Fixed delivery time. Simultaneous deliveries while ongoing time for both. Pressure, in the role of an outsourced worker. Simultaneous outsourcing to more than one client. Customer delays. Route planning, task time management, collective support, and negotiation of service demands to ensure production and safety.	Course taught by an experienced motorcyclist with discussions on the regulations developed. Consideration of variables and variability in the prescribed time. Autonomy over the task. Negotiation of turnaround points and parking with the city's traffic department. Material conditions: thermal box, company backup motorcycle, time for maintenance. Need to build an alternative to the current economic model.

Source: Diniz[24].

The ergonomics analysis of the activity showed that another world is possible when the experience of workers is recognized and validated as a valuable and essential resource for ensuring production and accident prevention. The analysis of the motorcycle couriers' activities revealed that the mediate determinants of the work situation (prescribed time *versus* real time, power relationships, management, and work organization) overlap with the immediate factors (traffic behavior), which can compromise the workers' room for maneuver. By helping to see and understand the world of workers from their perspective, the method allowed for the development of recommendations that had been little explored.

However, using the method requires a change in the observer's perspective, which must be developed by overcoming obstacles rooted in common sense and prevailing worldviews[11], such as blaming workers who are involved in accidents.

But what other world is actually possible if the activity analysis, although it provides an appropriate method to expose the effects of the economic model on production and workers, and the resulting recommendations originating, even when validated, do not have the means and strength to change the organizational, structural, and essential dimension of the work situation by itself? The market economy and the financialization of companies undermine any attempt or initiative, individual or collective, by workers to ensure their safety or that of the client, even in areas considered references on this subject, such as civil aviation. The case of Boeing and its 737 Max aircraft model, impacted by the neoliberal and financialized management of the airline, became emblematic by prioritizing shareholder dividends to the detriment of the safety management previously practiced by the company's workers[27]. In the case of motorcycle couriers, the individual or collective regulations practiced by the category acted within the boundaries and limitations of the space of freedom preserved at the time, aiming to shape a true aegis that would serve as a practical instrument to relieve the time pressure associated with the high service demand. With the advent of "uberization" work controlled by app-based platform companies in the provision of services (such as delivery)—all traces of autonomy that the category had for managing production and their own safety were removed, worsening the already precarious working conditions and relationships[28]. The transformation of working conditions towards greater precariousness runs counter to the accumulation of knowledge about working conditions and the activities of motorcycle couriers.

The case of the motorcycle couriers and their limited adoption of the research results by those involved in the process also confirms the thesis put forward by Daniellou[29] that the transformation of work is not an automatic byproduct of the activity analysis. In other words, analyses cannot be limited to merely identifying and publicizing the effects of the mediate determinants of the economic model. Transformation begins when the ergonomist intervenes and positions themselves as a catalyst and driver of processes aimed at improving working conditions.

Analysis of activity, weak signals, and HRO

The combined improvements in technical, organizational, and human reliability have elevated some systems to a level of safety that can be classified as "High Reliability Organizations" (HRO)[10]. The continuous decline in accident rates forms an oscillating and somewhat erratic asymptote, prompting safety management to seek new tools and preventive approaches to resume the downward curve and move closer to zero accidents, even in HRO. Although this goal is more of a long-term vision than an immediate possibility, as some safety professionals believe, there is a real societal demand, even in HRO such as civil aviation, to further reduce accidents, which, albeit rare, can be catastrophic.

This is where Ergonomics can intervene in existing systems, by creating new tools or improving existing ones. In this regard, there is still much to be done in terms of risk anticipation. A common turning point in various approaches is that prevention and learning based solely on the analysis of accidents, incidents, and anomalies are limited and always act in a corrective manner.

Analysis of everyday work and weak signals for accident prevention

To overcome the paradox of preventive measures that are no longer preventive, authors from various fields, such as Resilience Engineering[8], Safety II[9], or even the provocative proposal of "anarchist safety," focus on the analysis of everyday work[30]. Similar to activity-centered ergonomics, these authors acknowledge the difference between "work-as-done" and "work-as-imagined," reproducing the pair "prescribed work" and "day-to-day work," which requires the analysis of everyday work to understand risks before they manifest themselves as incidents or accidents. However, the concept of analyzing day-to-day operation still presents operational challenges, as pointed out by Lima and colleagues[31]:

In this perspective, the already old notion of 'weak signal' is both promising and scary: promising because it refers to the crucial stage of the premises of the specification by professionals of a degraded state of the system; scary because it remains difficult to theorize, especially at the phenomenological level [the study of the emergence of the phenomenon for the actor], and consequently, it is scarcely documented at the empirical level (p. 3).

Regarding situations of day-to-day operation, it is necessary to question not only the strength of the signal indicating a potential risk but also the very nature of the signal associated with a risk[31]:

When considered weak, the signal can represent two very different things depending on whether it is placed within a cognitive epistemology (cognition as an information processing system available outside the actor) or an ecological approach (cognition as the means and product of information emerging in the actor-environment coupling). In a cognitive perspective, the signal exists in the environment, and its "weak" nature refers to the difficulty of perception and interpretation closely linked to a degree of specialization. In an ecological approach, the signal does not exist before it emerges in the actor-environment coupling, and its "weak" nature refers to the fact that it has not yet taken shape as a "sign" with a clear meaning for the actor. It is then merely a discrepancy in the environment, a difference between the expected and the real (p. 3).

Certainly, investing in the capture of weak signals is an interesting way to advance safety issues based on the perspective of the actual activity of workers, but this requires an ecological approach, such as the Course of Action Analysis (CAA)[32].

The ontological hypotheses and semiological analysis proposed in this theoretical framework allow us to describe the part of human activity that can be apprehended subjectively by the actor and enable the ex ante analysis of pre-accidental situations, shedding light on the disruption caused by the accident during the activity that seemed normal[31] (p. 3).

As such, any organization wishing to produce safely and with quality must seek ways to identify weak signals present in work situations. Several organizations recognize this and, to varying degrees, aim to develop methods and devices to bring these signals to light, thereby learning from operational teams and evolving based on their own experience.

A new approach to Operational Experience Feedback for accident prevention

Attempts to develop Operational Experience Feedback (OEF), such as sharing accident analyses, incident or accident notification systems, and safety meetings (daily safety dialogues, safety minutes, etc.), generally focus on purely retrospective systems based on undesired events with already concluded outcomes. These are reactive safety approaches that have shown their limitations, mainly because the accidental context is often linked to a solely normative view of safety and the accountability of involved operators, restricting the ability to learn from the situation[33].

As a result, few elements of day-to-day work appear in these spaces, as well as the weak signals of the system. The traditional, reactive OEF developed by organizations fails to create a preventive environment involving various workers. It is essential to consider more comprehensive OEF systems that are not solely based on singular, undesired events with already defined outcomes, but that also include "day-to-day work"[34] where the undesired event did not necessarily occur but could have. In these situations, work activity can, at least partially, be unveiled and contribute to the safety field. As Amalberti[35] points out, the sequences of actions that lead to accidents often closely resemble those effective in preventing events, with minor differences between one and the other in the details of the activity.

Thus, it is a way of developing the organization based on its own experience and its ability to draw lessons from situations that have not yet caused problems. In other words, it involves prospective OEF methods that can be operationalized by creating institutionalized moments and spaces for confronting and discussing day-to-day work[36].

Ergonomics contribution to artifact design for human-machine integration (computerized systems)

The diagram in **Figure 1** represents three significant stages of safety development in the second half of the 20th century, which now seem to have reached a limit, requiring new approaches to human factors. From an ergonomics perspective, it is not a sequence of successive stages but rather parallel approaches which, although they had drifted apart to some extent, must now be integrated into a comprehensive safety system. The ergonomics contribution involves rethinking technical reliability and management systems based on OEF practices and methods. Above all, the emphasis is on how OEF devices contribute to organizational changes by creating spaces for autonomy, integrating actions at different hierarchical levels, and facilitating organization with upward and downward information flows. Another essential contribution of ergonomics, to complete this integrated safety framework, is collaborative design practices that enable the experience of workers to feed into technical reliability, a role that is typically limited to engineers.

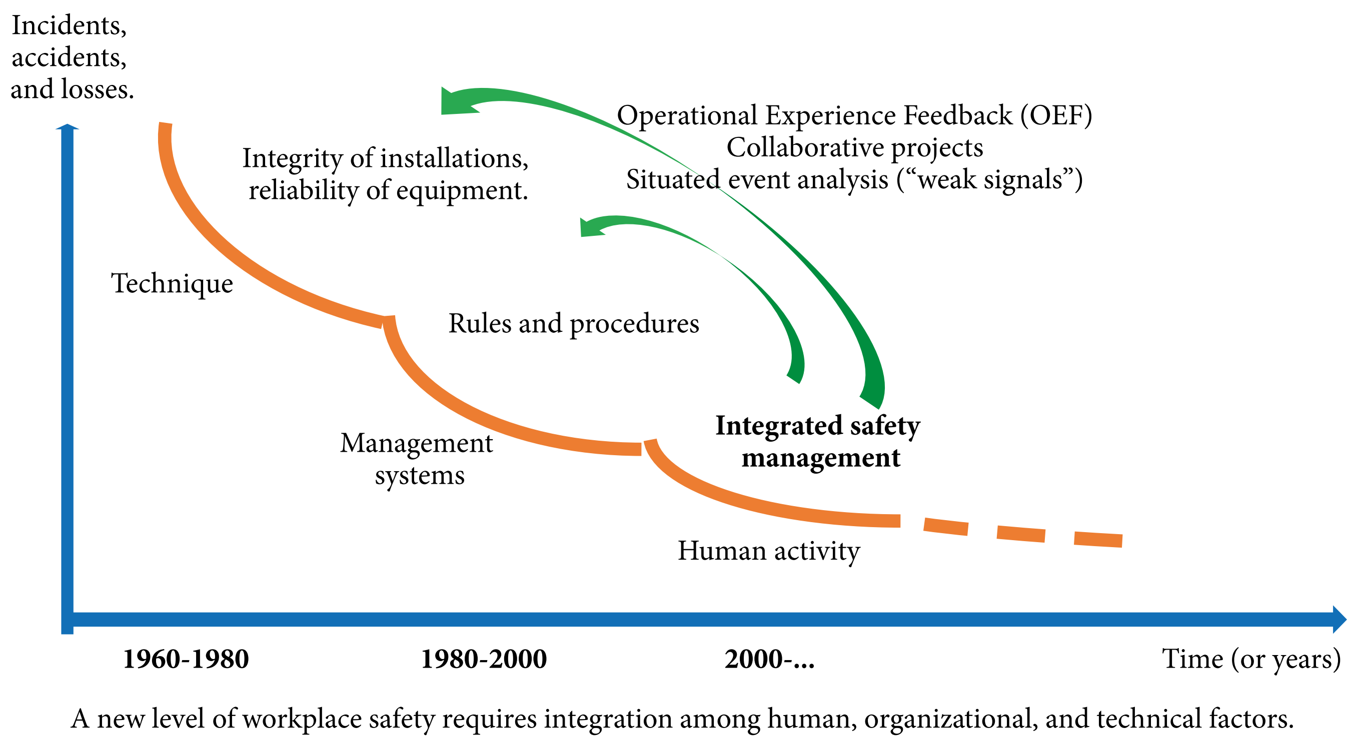

Figure 1 The new frontier of human and organizational factors in safety

Source: Adapted from Amalberti[7].

The intention of Ergonomics in design is to transform "technical artifacts" into "instruments", facilitating the appropriation process by workers. This process of instrumentation occurs when action schemes develop and merge with the functional properties of artifacts[37]. To illustrate the contribution of Ergonomics in the case of HRO, it is interesting to address the paradox of automation, which increases technical safety while decreasing human reliability. This situation was pointed out as early as the 1980s by Bainbridge[38], who highlighted various negative effects on operator performance resulting from how engineers developed the automation of technical systems. "The designer has the idea that the human operator is neither reliable nor efficient and should, therefore, be eliminated from the system" (p. 272). The contradiction is that by designing to exclude human intervention, considered the weak link in human-machine systems, engineers create situations that are sources of errors. What is gained, on the one hand, in technical reliability, is partly lost, on the other, due to the difficulties created for operators to maintain control over automated systems. When one attempts to eliminate the human element, the designer leaves the operator with only those tasks that cannot be automated. Consequently, the operator is responsible for an arbitrary set of tasks, with little thought given to supporting their activity[38]. For example, in an emergency, when human intervention is required, there are difficulties in accessing the necessary information to establish a diagnosis and regain manual control (for more on this, see the analysis of the Air France Flight 447 accident by Rocha and Lima[39]). In the end, a situation is created that leads to human error, not because operators are the weak link, but because the non-integrated development of human-machine systems leads to accident-prone situations:

> *Now, if the computer is being used to make decisions because human judgment and intuitive reasoning are inadequate in the context, then how does one know which decisions made by the computer should be accepted? The human operator has been assigned an impossible task to perform*[38] (p. 274).

These problems identified in the early days of automation are recurring today with the intensive use of computer-based technologies, based on the processing of vast amounts of data accumulated by process control systems, which are currently exploited by significant innovations grouped under the term Industry 4.0. These advances characterize a new technological paradigm, but still leave the role of human operators in these computerized and intelligent systems undefined. In the debates about Industry 4.0, more is said about the jobs that will disappear than about those that will remain. However, as in other periods of technological revolution, work will not cease to exist, but the nature and context of human activity will be profoundly transformed. To prevent the paradoxes of automation from recurring, studies on human activity are needed, along with the development of technological knowledge to design interfaces suitable for Industry 4.0. It must evolve towards Industry 5.0, designed to support the activity of operators who are in charge of monitoring and rectifying automated systems' deviations.

Ergonomics relies on the cognitive analysis of surveillance activity to design various interfaces that support the operator's activity, especially in disturbance situations such as starts, stops, or unforeseen instabilities. Cognitive analysis of the operator activity is the basis for designing integrated systems to, for example, increase sensitivity to the context and the operators' situational skill. Thus, the concept of "loss of situational awareness" can take on a more concrete meaning and cease to be merely a substitute for human error, as pointed out by Dekker[40]. Similarly, alarm management systems can be optimized, now redefined based on the situation experienced by operators, and not merely as indications of system failures that replicate the technical system configuration.

Final remarks

The current challenge in safety is to create spaces for the recovery of individual experiences that are capable, on the one hand, of dealing with day-to-day work, and everyday situations and, on the other, free from the burden of guilt, allowing the development of autonomy based on professional experience. In high-risk systems, forms of OEF are often absent. In HRO, OEF can be more or less effective, depending on the organization. However, spaces persist where work is not discussed while simultaneously aiming to assign blame and penalties to those involved in the highlighted situation. There is, therefore, a need to incorporate work studies into the development of OEF systems capable of creating genuinely safe environments.

The resumption of the downward curve in accident rates can no longer happen as it did in the second half of the 20th century. Vulnerable systems, such as motorcycle couriers, can certainly benefit from regulatory actions and improvements in technical reliability via interventions on motorcycles and urban roads. However, the accident preventive barriers in place to promote safety in a context of flexible working relationships almost nullify the possibility of implementing significant improvements in work conditions. Ergonomic analyses offer alternative actions between unfavorable work relationships and the impotence that leads to the naturalization of accidents.

High Reliability Organizations, which seem to have found a limit, can still enhance safety by taking advantage of recent advances in the analysis of situated action and cognition, and by building spaces for discussing work, enabling the Operational Experience Feedback from field experience to fuel prevention actions. In this case, what currently appears as a limit should be considered merely an organizational barrier that prevents the emergence of workers' knowledge, capable of recognizing and addressing the weak signals of the organization, which, when properly instructed, can bring out day-to-day work situations. This is the new frontier of safety that Ergonomics can help overcome.

References

1. Lima FPA, Rabello L, Castro M, editors. Conectando saberes: dispositivos sociais de prevenção de acidentes e doenças no trabalho. Belo Horizonte: Fabrefactum; 2015.
2. Bratz D, Rocha R, Gemma S. Engenharia do trabalho, saúde, segurança, ergonomia e projeto. Santana de Parnaíba: Ex Libris Comunicação; 2021.
3. Falzon P, editor. Ergonomia. São Paulo: Edgard Blucher; 2012.

4. Fonseca ED, Lima FPA, Duarte FJCM. From construction site to design: the different accident prevention levels in the building industry. Saf Sci. 2014;70:406-18.

5. Coutarel F, Daniellou F, Dugué, B. Interroger l'organisation du travail au regard des marges de manoeuvre en conception et en fonctionnement : la rotation est-elle une solution aux TMS? PISTES. 2003;5(5-2):1-27.

6. Messias IA, Nascimento A, Rocha R. Job rotation as a legal requirement: analysis of the participatory approach in acceptance and workers' perception at a meatpacking plant. Gest Prod. 2022;29:e10522.

7. Amalberti R. Gestão da segurança. Presidente Prudente: Gráfica CS Eireli; 2016.

8. Hollnagel E, Woods DD, Leveson NG. Resilience engineering: concepts and precepts. Aldershot: Ashgate; 2006.

9. Hollnagel E. Safety-I and Safety-II: the past and the future of safety management. Farnham: Ashgate; 2014.

10. Roberts KH. New challenges in organizational research: high reliability organizations. O&E. 1989;3(2):111-25.

11. Lima FPA. A formação em ergonomia: reflexões sobre algumas experiências de ensino da metodologia de Análise Ergonômica do Trabalho. In: Kiefer C, Fagá I, Sampaio MR. Trabalho – educação – saúde: um mosaico em múltiplos tons. São Paulo: Fundacentro; 2001. p. 133-48.

12. Falzon P. Natureza, objetivos e conhecimentos da ergonomia: elementos de uma análise cognitiva da prática. In: Falzon P, editor. Ergonomia. São Paulo: Edgard Blucher; 2012. p. 3-19.

13. Reason J. The human contribution: unsafe acts, accidents and heroic recoveries. London: CRC Press; 2008.

14. Llory M, Montmayeul R. O acidente e a organização. Belo Horizonte: Fabrefactum; 2014.

15. Wisner A. Arretons d'opposer cause technique et cause humaine. Santé et Travail. 1991;(2):29-35.

16. Vilela RAG, Iguti AM, Almeida IM. Culpa da vítima: um modelo para perpetuar a impunidade nos acidentes do trabalho. Cad Saude Publica. 2004;20(2):570-9.

17. Woods D, Dekker S, Cook R, Johannesen L, Sarter N. Behind human error. Farnham: Ashgate; 2004.

18. Le Coze JC. Trente ans d'accidents : le nouveau visage des risques sociotechnologiques. Toulouse: Octarès; 2016.

19. Reason J. Human error. Cambridge: Cambridge UP; 1990.

20. Reason J. Managing the risks of organizational accidents. Farnham: Ashgate; 1997.

21. Perrow C. Normal accidents: living with high-risk technologies. New York: Basic Books; 1984.

22. Vaughan D. The challenger launch decision: risky technology, culture, and deviance at NASA. Chicago: University of Chicago Press; 1996.

23. Rasmussen J, Duncan K, Leplat J, editors. New technology and human error. Chichester: John Wiley and Sons; 1987.

24. Diniz EPH. As condições acidentogênicas e as estratégias de regulação dos motociclistas profissionais: entre as exigências de tempo e os constrangimentos do espaço [dissertation]. Belo Horizonte: Universidade Federal de Minas Gerais; 2003.

25. Lima FPA. Paradoxos e contradições do direito de recusa. In: Lima FPA, Rabello L, Castro M, editors. Conectando saberes: dispositivos sociais de prevenção de acidentes e doenças no trabalho. Belo Horizonte: Fabrefactum; 2015. p. 173-212.

26. Leplat J. Aspectos da complexidade em Ergonomia. In: Daniellou F, coordenador. A Ergonomia em busca de seus princípios: debates epistemológicos. São Paulo: Edgard Blucher; 2004. p. 57-77.

27. Queda livre: a tragédia do caso boeing [Documentary]. Direction: Rory Kennedy. [place unknown]: Imagine Documentaries; 2022.

28. Kalil RB. A regulação do trabalho via plataformas digitais. São Paulo: Edgard Blucher; 2020.

29. Daniellou F. Apresentação à edição brasileira. In: Daniellou F, coordinator. A Ergonomia em busca de seus princípios: debates epistemológicos. São Paulo: Edgard Blucher; 2004. p. vii-x.

30. Dekker S. The safety anarchist: relying on human expertise and innovation, reducing bureaucracy and compliance. London: Routledge; 2018.

31. Lima FPA, Duarte F, Sznelwar LI, Rocha R, Drakos A, Flandin S. La perception des signaux faibles : propositions pour l'analyse de l'activité dans les organisations à risques. 56ème Congrès SELF : Vulnérabilités et Risques Émergents : Penser et Agir Ensemble pour Transformer Durablement; 6-8 juillet 2022; Genève.

32. Theureau J. Le cours d'action : méthode élémentaire. Toulouse: Octarès; 2004. Trad. Bras. ampliada: O Curso da Ação. Método Elementar. Belo Horizonte: Fabrefactum; 2014.

33. Amalberti R, Gremion C, Auroy Y, Michel P, Salmi R, Parneix P, et al. Les systèmes de signalement des événements indésirables en médecine. Etudes et Resultats. 2007;(584):1-8.

34. Assunção AA, Lima FPA. A contribuição da ergonomia para a identificação, redução e eliminação da nocividade do trabalho. In: Mendes R. Patologia do trabalho. Rio de Janeiro: Atheneu; 2003. p. 1768-89.

35. Amalberti R. The paradoxes of almost totally safe transportation systems. Saf Sci. 2001;37(2):109-26.

36. Rocha R. Espaços de debate e poder de agir na construção da segurança das organizações. Laboreal. 2017;13(1):1-9.

37. Rabardel P, Béguin P. Instrument mediated activity: from subject development to anthropocentric design. Theor Issues Ergon Sci. 2005;6(5):429-61.

38. Bainbridge L. Ironies of automation. In: Rasmussen J, Duncan K, Leplat J, editors. New technology and human error. New York: John Wiley; 1987. p. 271-83.

39. Rocha R, Lima FPA. Erros humanos em situações de urgência: análise cognitiva do comportamento dos pilotos na catástrofe do voo Air France 447. Gest Prod. 2018;25:568-82.

40. Dekker S. The field guide to understanding 'human error'. Boca Raton: CRC Press; 2014.

Authors' contributions: Diniz EP, Lima FPA, and Simões RR were responsible for the following aspects: (1) substantial contribution to the conception, study design, data analysis, and interpretation; (2) participation in drafting preliminary versions and critically reviewing the manuscript; (3) approval of the final version to be published; (4) agreement to be accountable for all aspects of the work and ensuring that issues related to the accuracy or integrity of any part of the work have been properly investigated and resolved. The authors assume full responsibility for all aspects of the study.

Data availability: the entire dataset supporting the results of this study has been published in the article itself.

Funding: the authors declare that the study was not funded.

Competing interests: the authors declare that there are no conflicts of interest.

Presentation at a scientific event: the authors state that the study has not been presented at a scientific event and is not based on a dissertation or thesis.

Received: January 30, 2023
Revised: September 27, 2023
Approved: September 29, 2023

Editor-in-Chief
Ada Ávila Assunção