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Extended reality technologies and the Metaverse: what implications for employees' health and safety?

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Abstract

The paper investigates both opportunities and challenges in the field of occupational health and safety (OSH) connected to the implementation of extended reality (XR) technologies and the Metaverse in the workplace. In particular, after addressing the current definitional ambiguities related to these technologies, the analysis considers their dual role as instruments of innovation and inclusion on one hand, and as sources of new risks for OHS on the other. Special attention is paid to the phenomenon here defined as "unwanted virtual interactions" between the employee's and their colleagues or people outside the organization (like costumers). Considering the nature and the functioning of such technologies, the paper argues that to make really effective the employer's preventive system the participation of all its actors is crucial and must be emphasized, especially looking at the employee.

Keywords: Occupational Health and Safety; Extended Reality (XR); Metaverse; Employer Liability; Employee's duty of cooperation.

"*Imagine that a human being (you can imagine this to be yourself) has been subjected to an operation by an evil scientist. The person's brain (your brain) has been removed from the body and placed in a vat of nutrients which keeps the brain alive. The nerve endings have been connected to a super-scientific computer which causes the person whose brain it is to have the illusion that everything is perfectly normal. There seem to be people, objects, the sky, etc.; but really all the person (you) is experiencing is the result of electronic impulses travelling from the computer to the nerve endings. The computer is so clever that if the person tries to raise his hand, the feedback from the computer will cause him to 'see' and 'feel' the hand being raised. Moreover, by varying the program, the evil scientist can cause the victim to 'experience' (or hallucinate) any situation or environment the evil scientist wishes. He can also obliterate the memory of the brain operation, so that the victim will seem to himself to have always been in this environment. It can even seem to the victim that he is sitting and reading these very words about the amusing but quite absurd supposition that there is an evil scientist who removes people's brains from their bodies and places them in a vat of nutrients which keep the brains alive*".

H. Putnam, *Reason, Truth and History,* Cambridge University Press, Cambridge, 1981, 6.

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1. From the "infosphere" to the Metaverse.

The defining feature of digitalization, which distinguishes it from any previous evolutionary process experienced by mankind, is its ability to 'dissolve' elements of the physical world and transpose them into a new dimension: the *virtual* realm.

Just like the Platonic "hyperuranium", the virtual dimension stands apart from the physical (or rather *analog*) reality in which human life has so far been traditionally rooted.

However, unlike the Platonic world of ideas that was described as "colourless", "formless", and "intangible to human senses",[1] the virtual dimension has become subject to human 'colonization' thanks to the mediation of digital devices, which operate as 'points of contact' between *analog* and *virtual* realms.

The human 'colonization' of the *virtual* dimension is an ongoing process closely influenced by the state of technological advancement, according to which it is possible to identify at least three distinct phases.

The first corresponds to the early stages of digitalization, when, due to their complexity and the high costs associated with their production, digital devices were rare and deployed almost only in specific sectors, such as scientific and military research. As a consequence, during this period the 'points of contact' between analog and virtual dimensions were very limited, and so they remained sharply separated from one another.

The second phase is the one we are currently living in. It began with the exponential advances in information and communication technologies (ICTs), which made digital devices increasingly affordable, user-friendly, and compact. As a result, these devices have become so widespread that today almost every person owns at least one, and through it has instant and continuous access to the virtual realm.

As noted, such unprecedented proliferation of the 'portals' between the two dimensions, combined with factors such as digitalization of information, the expansion of interconnected networks, the development of cloud computing, and advancements in AI and automation, appears to have erased the remaining boundaries between the two realms, or rather "between *here* (*analog, carbon-based*, and *offline*) and *there* (*digital, silicon-based*, and *online*)".[2]

This progressive blurring of boundaries has given rise to a new hybrid dimension, the so-called "*infosphere*", which seamlessly integrates elements of both. The most immediate evidence of this new integrated reality is that nowadays asking someone whether they are "online" or "offline" sounds completely out of date. Our daily lives demonstrate how much of human activity now takes irreversibly place through digital devices: from social interactions, which benefit from apps, e-mail and social networks, to activities including work, shopping, travel and even dealing with public authorities (tax payments, official notifications or the issuance of identity documents are now routinely handled in the digital realm).

In the employment sector, the rise of the infosphere has influenced at least two aspects, highlighting the shift from traditional organizations, where achieving productive goals

[1] Plato, *Phaedrus*, 247, c-e.

[2] Floridi L., *La quarta rivoluzione. Come l'infosfera sta trasformando il mondo,* Raffaello Cortina Editore, Milan, 47; *see* also Accoto C., *Il mondo in sintesi. Cinque brevi lezioni di filosofia della simulazione,* Egea, Milan, 2022.

depended on the concentration of all productive factors within the same (physical) location, to more advanced and digitalized productive models.

The first aspect relates to the exponential growth of remote work, which reshapes modern workplaces' physical structure, enabling employees to perform an increasing number of tasks outside factories or offices as traditionally conceived, potentially turning any place into a workplace.[3]

The second profile concerns the rise of heavily digitized productive models, such as those defining the gig economy in the service sector, where the core and design of the productive process rests quite entirely on digital infrastructure (the platforms) based on algorithms.[4]

It seems, however, that the infosphere, as known to date, does not represent the final step of the human journey of 'colonization' of the virtual realm.

The advent of extended reality technologies (XR) and moreover of the Metaverse is poised to usher humanity into the third phase of this journey, where the *virtual* component of the infosphere could overcome and become dominant over the *analog* one. The expanding scope and nature of activities that can be carried out within the virtual dimension of the infosphere raise the question of whether, in the future, users might increasingly choose to conduct significant aspects of their lives in the *virtual* realm, disengaging, potentially almost entirely, from the *analog* world.[5]

The growing diffusion of these technologies (XR and the Metaverse) has also raised the attention of law scholars, who explore the legal implications of actions in virtual spaces[6] under private law (such as celebrating marriages[7] or signing contracts)[8] as well as under

[3] One of the evidences of this trend is the so-called 'digital nomadism', which raises numerous problems precisely in the area of health and safety protection, on which *see* Tardivo D., *Digital nomads' health and safety: the European perspective*, in Menegatti E. (ed.), *Law, Technology and Labour*, Italian Labour Law e-Studies, Bologna, 2023, 246-260.

[4] Unlike 'traditional' employers, who are physically present in the workplace and directly manage workers, these platforms act as intermediaries, connecting individuals with their tasks through algorithms and digital interfaces, often without any direct human oversight or interaction; on the implications on labour relations *see*: De Stefano V., *The Rise of the "Just-in-Time Workforce": On-Demand Work, Crowdwork, and Labor Protection in the "Gig Economy",* in *Comparative Labor Law & Policy Journal*, 37, 3, 2016, 471-504; for an interesting historical perspective see Finkin M., *Beclouded Work in Historical Perspective*, in *Comparative Labor Law & Policy Journal*, 37, 3, 2016, 603-618; on the qualification of the employment relationship in light of the case law of the European Court of Justice *see*: Menegatti E., *Taking EU labour law beyond the employment contract: The role played by the European Court of Justice,* in *European Labour Law Journal,* 1, 2020, 26-47.

[5] Slater M., Gonzalez-Liencres C., Haggard P., Vinkers C., Gregory-Clarke R., Jelley S., Watson Z., Breen G., Schwarz R., Steptoe W., Szostak D., Halan S., Fox D., Silver J., *The Ethics of Realism in Virtual and Augmented Reality,* in *Frontiers in Virtual Reality*, 1, 2020, 1; Fuselli F., *Metaverso e neurotecnologie: una ricognizione,* in *Journal of Ethics and Legal Technologies*, 5, 2, 2023, 5.

[6] For an overview see: Dwivedi Y. K. *et al.*, *Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy*, in *International Journal of Information Management*, 2022, 66; *see* also Koos S., *Digital globalization and law*, in *Lex Scientia Law Review,* 6, 1, 2022, 33; Fuselli S., *Brain-Computer Interface e soggettività agente. Considerazioni etico-giuridiche*, in Moro P. (ed.), *Etica, diritto e tecnologia*, FrancoAngeli, Milan, 2021, 151.

[7] It is the case described by Zanellato M., *Questo matrimonio s'ha da fare (nel Metaverso). Nuovi luoghi, stesse persone,* in *Journal of Ethics and Legal Technologies*, 5, 2023, 62.

[8] Brey P., *The physical and social reality of virtual worlds,* in Grimshaw-Aagaard M. (ed.), *The Oxford Handbook of Virtuality,* Oxford University Press, Oxford, 2014, 42.

criminal law.[9] The debate has begun also among labour law scholars,[10] given that XR technologies and the Metaverse are already used by employers in many sectors with the purpose, among others, of supporting remote collaboration and interactions between employees,[11] improving data visualization and analysis,[12] supporting design activities,[13] providing a better customer experience,[14] etc.

As discussed below, the integration of XR technologies and the Metaverse into the workplace offers several opportunities but presents also complex challenges. This is particularly true when it comes to workers' health and safety.[15] Unlike other issues, where it may be tolerable to wait for the result of the academic and professional debate, in the field of OSH it is essential to address potential risks in advance given that, once injured, the workers' health may not be fully restorable.

[9] Among the others: Bellini O., *Virtual Justice: Criminalizing Avatar Sexual Assault in Metaverse Spaces*, in *Mitchell Hamline Law Review*, 50, 1, 2024, 77.

[10] Among the others *see*: Biasi M., Murgo M., *The virtual space of the Metaverse and the fiddly identification of the labor law,* in *Italian Labour Law e-Journal*, 16, 1, 2023, 1; Nogueira Guastavino M., Mangan D., *The metaverse matrix of labour law,* in *Italian Labour Law e-Journal*, 16, 1, 2023, 13; Sipka P., *Potential challenges of working in a virtual space*, in *Italian Labour Law e-Journal*, 1, 2023, 53; Lamberti F., *Il metaverso: profili giuslavoristici tra rischi nuovi e tutele tradizionali,* in *Federalismi.it,* 4, 2023, 205; Maio V., *Diritto del Lavoro e metaverso. Se il Lavoro non è un (video)gioco,* in *Labour & Law Issues*, 2, 2022, 42; Donini A., Novella M., *Il metaverso come luogo di Lavoro,* in *Labour & Law Issues,* 2, 2022, 4; Peruzzi M., *"Almeno tu nel metaverso". Il diritto del Lavoro e la sfida dei nuovi spazi digitali,* in *Labour & Law Issues,* 2, 2022, 66; Martone M., *Prime riflessioni su lavoro e metaverso,* in *Argomenti di Diritto del Lavoro,* 6, 2022, 1131; more recently: Valenti C., *La destrutturazione spazio-temporale del lavoro: quali rischi dalle tecnologie immersive?,* in *Diritto della Sicurezza sul lavoro,* 2, 2024, 102. Reflecting on the implications for the industrial relations system: Pisani F., *Collective Labour Relations in the Metaverse*, in *Italian Labour Law e-Journal*, 1, 2023, 41.

[11] Companies like Accenture are committed to create immersive work environments to facilitate cooperation among remote teams: "Accenture believes the future of meeting, learning and working together will combine physical and virtual experiences to transform the enterprise (…) Accenture's Nth floor metaverse is enabling employees to meet, learn and collaborate in new ways". *See*: Accenture, *Going beyond with extended reality*, available at https://www.accenture.com/se-en/insights/technology/going-beyond-extended-reality . This goal aims also the "Meta Horizon Workrooms" described on https://forwork.meta.com/it/en/horizon-workrooms/ (last access on May 13, 2025).

[12] *See* the case of "*BMW iFACTORY*", described at www.all-about-industries.com/virtual-production-launch-at-bmw-a-12e7a13ff8d5183c49fd42ce6795d571/ (last access on May 13, 2025).

[13] See: Sahebnasi J. M. *et al.*, *Exploring the Potential of Generative AI in Prototyping XR Applications,* in Wang N. *et al.* (eds.), *Proceedings of the First Workshop on Prototyping and Developing Real-World Applications for Extended Reality (RealXR) 2024,* CEUR Workshop Proceedings, CEUR-WS.org, 2024.

[14] Among the others, see the case of Nike described at www.invrsion.com/invrsion-for-nike (last access on May 13, 2025) or IKEA, but also L'Oreal, which aims in the near future to allow customers to try on cosmetic products by simulating tactile sensations, see www.retailinstitute.it/loreal-accelera-sullinnovazione-dalla-pelle-stampata-in-3d-al-packaging-sostenibile/ (last access on May 13, 2025).

[15] For an overview see the reports by European Agency for Safety and Health at Work (EU-OSHA), *Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025*, 2018, available at www.osha.europa.eu/en/publications/foresight-new-and-emerging-occupational-safety-and-health-risks-associated (last access on May 13, 2025), and *Worker exposure to virtual and augmented reality and metaverse technologies: How much do we know?,* 2024, available at www.osha.europa.eu/en/publications/worker-exposure-virtual-and-augmented-reality-and-metaverse-technologies-how-much-do-we-know (last access on May 13, 2025). In the literature *see*: Souchet A. D., Lourdeaux D., Hancock P. A., *Design guidelines for limiting and eliminating virtual reality-induced symptoms and effects at work: A comprehensive, factor-oriented review*, in *Frontiers in Psychology,* 2024, 14; Souchet A. D. *et al., A narrative review of immersive virtual reality's ergonomics and risks at the workplace: Cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload*, in *Virtual Reality,* 27, 1, 2023, 19; Dwivedi Y. K. *et al.*, *Exploring the darkverse: A multi-perspective analysis of the negative societal impacts of the metaverse*, in *Information Systems Frontiers,* 25, 5, 2023, 2071.

For this reason, the paper aims to contribute to the debate exploring both positive and negative implications for occupational health and safety of using XR and the Metaverse in professional environments.

To this end, firstly, the paper adopts a classification of the various immersive reality technologies (para. 2). Second, it explores the unprecedent potential benefits of integrating XR and the Metaverse into preventive systems (para. 3). Third, it critically assesses the physical and psychosocial risks that these technologies may pose to workers (para. 4). The paper then evaluates whether the preventive approach enshrined in the Framework Directive (EC Directive 89/391) remains effective in addressing the challenges introduced by such technologies, paying particular attention on the role of key actors of the health and safety systems: the employer, but also the supervisor, the workers' safety representatives, and the employee himself (para. 5). Finally, the question arises as to whether a truly participated prevention system is preferable to a system based on the continuous and pervasive monitoring of workers, which is made much easier through this type of technology (par. 6).

2. The search for definitions.

The first challenge in assessing the impact of XR technologies and the Metaverse in the workplace is the lack of clear and consistent definitions.

Considering the XR, every time a new device is brought to market, it is promptly labelled with a wide range of terms and acronyms. In addition, professional media outlets often apply different concepts to refer to the same product.[16] The result is that looking at the commercial landscape, it is easy to come across definitions such as "virtual reality" (VR), "augmented reality" (AR), and "extended reality" (XR), but also "media-generated reality" (MGR), "mixed reality" (MR), "assisted reality" (AsR), "digital reality" (DR), "virtual environments" (VE), "cross reality" (CR), "virtual worlds" (VW).[17]

The Metaverse poses the same challenge. While there is a general understanding of it as a fully immersive technology, its precise and univocal definition remains unclear. A 2022 study, for instance, identified 48 different definitions of the Metaverse.[18] Then, it should be considered that there are multiple virtual spaces designed and implemented by different companies for purposes other than work, including recreational or gaming purposes.[19]

[16] Laato S., Xi N., Spors V. *et al., Making Sense of Reality: A Mapping of Terminology Related to Virtual Reality, Augmented Reality, Mixed Reality, XR and the Metaverse*, in *Proceedings of the 57th Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences*, 2024, 6625.a.

[17] Rauschnabel P. A., Reto F., Hinsch C., Shahab H., Alt F., *What is XR? Towards a Framework for Augmented and Virtual Reality*, in *Computers in Human Behavior*, 133, 2022, 1.

[18] Park S. M., Kim Y. G., *A Metaverse: Taxonomy, components, applications, and open challenges,* in *IEEE Access,* 10, 2022, 4214-4216, available at https://ieeexplore.ieee.org/document/9667507 (last access on May 13, 2025); one year later Dolata M., Schwabe G., *What is the metaverse and who seeks to define it? Mapping the site of social construction*, in *Journal of Information Technology*, 38, 3, 2023, 239, still define the Metaverse "as a new, continually evolving sociotechnical phenomenon" or "as a dynamic, moving target."

[19] Donini A., Novella M., *Il metaverso come luogo di Lavoro,* nt. (10), 7-8; *see* also Lamberti F., *Il metaverso: profili giuslavoristici tra rischi nuovi e tutele tradizionali,* nt. (10), 205.

To overcome this definitional uncertainty, this paper adopts a systematization of the most significant definitions, to which it seems that all others can be traced.

The first definition that comes into consideration is "virtual reality" (VR). It can be described as an immersive experience in a visually isolated three-dimensional space, without meaningful interaction of the user with the physical world outside the simulation.[20]

Then, there is "augmented reality" (AR), characterized as an experience that overlays virtual elements onto the user's physical environment, with varying degrees of integration between the virtual and physical components.

In turn, both VR and AR, as well as other definitions, fall under the broader concept of "extended reality" (XR), which serves as an 'umbrella term' for technologies that use head-mounted displays and is widely adopted in academic literature and industry practice.[21]

Regarding the Metaverse, the many definitions mentioned above seem to converge on some fundamental characteristics.[22] They include immersive connectivity that engages both cognitive and sensory levels. Then, the Metaverse is pervasive in the scope of activities that can be carried out within it (ranging, as said, from recreational and social interactions to economic, financial, and legal transactions), as well as in the potential frequency of access. Additionally, it is persistent, continuing to exist and evolve even when users are not logged in, much like the real world, and it is also highly virtualizing, allowing individuals to project themselves into an alternative world through avatars.[23] Finally, it is designed to appear realistic and credible to those who access and interact with it as users.

All these features make it clear why it has been noted that the Metaverse strengthens the virtual dimension of the "infosphere", making the analog one recessive. But there is a case where the analog dimension may even disappear almost entirely: when the Metaverse is merged with Brain-Computer Interface (BCI) technologies.

[20] Rauschnabel P. A., Reto F., Hinsch C., Shahab H., Florian A., *What is XR? Towards a Framework for Augmented and Virtual Reality*, nt. (17), 2-3, note that at the beginning VR "were panoramic paintings that sought to fill an individual's field of view and make the viewer feel as if he/she were actually embedded in the scene. Whereas panoramic paintings utilize foreshortening to create a feeling of presence in a scene, stereoscopic photo viewers more effectively used this concept to create a realistic perception of "being there". The first widespread use of technology that resembled contemporary VR was the Link Trainer application used to train pilots before and during World War II. When we think of VR today, most picture a head mounted system that occludes information from the environment while presenting information depicting a virtual environment to the user. These 'head-mounted displays' (HMDs) were initially designed for gaming and entertainment, but usage has gradually broadened to include areas like job training, prototyping, marketing, and tourism."

[21] Çöltekin A. *et al.*, *Extended reality in spatial sciences: a review of research challenges and future directions,* in *International Journal of Geo-Information*, 9, 439, 2020, 1, argue that "the terms virtual, augmented, and mixed reality (VR, AR, MR) refer to technologies and conceptual propositions of spatial interfaces studied by engineering, computer science, and human-computer-interaction (HCI) researchers over several decades. Recently, the term 'extended reality' (or XR) has been adopted as an umbrella term for VR/MR/AR technologies." *See* also: Rauschnabel P. A., Reto F., Hinsch C., Shahab H., Alt F., *What is XR? Towards a Framework for Augmented and Virtual Reality,* nt. (17), 1.

[22] Reggio F., *Tecnologia per, nonostante, o sull'essere umano? Tracce per uno 'human based design' della tecnologia digitale*, in *Journal of Ethics and Legal Technologies*, 5, 2, 2023, 35; *see* also: Weinberger M., *What is Metaverse? A definition based on qualitative meta-synthesis,* in *Future Internet,* 14, 310, 2022, 1.

[23] Bale A. S., Ghorpade N., Hashim M. F., Vaishnav J., Almaspoor Z., *A comprehensive study on metaverse and its impacts on humans*, in *Advances in Human-Computer Interaction,* 1, 2022, 1.

Even though both XR technologies and the Metaverse usually work through head-mounted visors,[24] they do not represent the only "portals of access" to virtual reality. In fact, for several decades BCI technologies have enabled the direct connection of brain activity to external devices, bypassing conventional musculoskeletal activation pathways. Nowadays, BCIs are increasingly employed for a wide range of purposes, such as assisting individuals who can no longer rely on their bodies' natural neural transmission channels, controlling drones, or enhancing video gaming experiences.

In very simple terms, such technologies work with a specialized software system which detects, encodes, and converts brain activity into a digital signal, allowing users to operate external devices without using their hands or any other body parts. This means that an individual can move something in the analog dimension without physically moving.

However, what interests here is that digital conversion of neural impulses is not limited to "outbound" signals as output. The reverse process is also possible, transmitting digital signals directly to the brain as input. For example, by stimulating the brain regions responsible for tactile sensations, it may be possible to create the sensation of touching an object that does not physically exist.[25] Similarly, olfactory areas could be activated to create the perception of scents from virtual environments.

Should BCI technologies be fully developed in the near future, addressing the serious safety risks and high costs associated with brain implantation, they could integrate seamlessly with the Metaverse. This integration could make the use of headsets unnecessary, enabling a fully immersive virtual experience and almost completely erasing the user's interactions within the analog dimension.

Nevertheless, considering that at the moment these are residual examples, this paper will consider only the Metaverse technology requiring the use of visors.

3. XR technologies, the Metaverse and occupational health and safety: opportunities...

As mentioned, the implementation of XR technologies and the Metaverse in the workplace offers numerous benefits to employers, particularly in enhancing employee

[24] Fang W. *et al.*, *Head-mounted display augmented reality in manufacturing: A systematic review*, in *Robotics and Computer–Integrated Manufacturing*, 83, 2023, 2, note that "since the release of Google Glass in 2012, the HMD AR system acquires unprecedented attention, followed by lots of commercial HMD AR glass (e.g. Moverio BT-300, Hololens 1 and 2, Magic Leap one, and so on). Because of its ability to display operating information directly in the worker's field of view (FOV), which acquires an increasing interest in HMD AR aided manufacturing activities. Especially in the past few years, the new HMD AR systems are lighter than previous ones and have the feature of a larger FOV, which is ideal for manufacturing sections by allowing hands-free operation. The number of HMD AR applications in industrial domains has continuously increased over the past decade"; however, they note (22) that "the weight of the HMD AR device" still remains "a point of criticism related to the human factor, causing increasing discomfort and having some safety implications, such as being distracted while walking may result in slips and fall-related injuries on the shop floor."

[25] Fuselli F., *Metaverso e neurotecnologie: una ricognizione,* nt. (5), 12; *see* also: Hughes C., Herrera A., Gaunt R., Collinger J., *Bidirectional brain-computer interfaces,* in Ramsey N. F., del R. Millán J. (eds.), *Handbook of Clinical Neurology,* Elsevier, Amsterdam, 2020, 168.

productivity, efficiency, engagement, and collaboration, while also reducing organizational costs and lowering the carbon footprint of their organizations.[26]

In the field of occupational health and safety, these technologies could have positive impacts as well. In particular, they may affect at least five areas: employee training, workplace design, risk assessment, employees' collaboration and assistance, and support in emergency management.

The potential of such technologies in worker training and education is substantial.[27] Initially, they were limited to a few industries like aviation for pilot training. On the contrary, nowadays they are applied across many sectors, including high-risk industries where training "in person" should be conducted in potentially dangerous environments,[28] like construction, mining, oil and gas, chemical or biochemical engineering.

By creating immersive, realistic, but controlled environments, XR technologies and the Metaverse offer employees the opportunity to practice critical tasks (like operating heavy machinery or handling toxic materials, working in confined spaces or places suspected of pollution) without exposure to actual dangers. This fosters their decision-making and confidence before stepping into the real work environment, where risks are real too.

The benefits in the field of training and education can be appreciated also beyond high-risk sectors, for instance when these technologies are used in favour of specific categories of workers. This is the case of young or newly hired employees who are less familiar with the work environment and its specific risks and to whom the employer's duty of protection is interpreted by Courts more strictly.[29] Through these technologies, these groups of workers can enhance their awareness by engaging with highly detailed and fully interactive virtual environments, thereby reducing the risk connected to their inexperience.

A second benefit relates to workplace design, aimed at enhancing safety and ensuring compliance with ergonomic principles. Architects and engineers are increasingly using XR and the Metaverse to design and project workplaces. For example, they can create walkthroughs of office spaces before construction begins, allowing them to experience a space, test different layouts, and make real-time adjustments based on users' feedback. This

[26] From a financial and environmental perspective, XR technologies help businesses cut costs by reducing the need for physical prototypes, travel, and printed materials. Virtual prototyping speeds up product development while minimizing material waste, and immersive meetings or training sessions lower travel expenses and carbon footprints.

[27] Maio V., nt. (10), 53.

[28] Grassini S., Laumann K., *Evaluating the use of virtual reality in work safety: A literature review*, in Baraldi P., Di Maio F., Zio E. (eds.), *Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference,* Research Publishing, Singapore, 4964-4971.

[29] For an Italian case *see* Cass. 10 January 2013, No. 536 stating "The duty of safety incumbent on the employer pursuant to Article 2087 of the Italian Civil Code is particularly intense in the case of young and professionally inexperienced workers, and is exalted in the presence of apprentices for whom the law lays down precise obligations of education and training, without the imprudence of the injured party in taking a collaborative initiative in the context of which the accident occurred being of any importance. In the case considered, an accident had occurred to a worker who, while bending an iron rod, had been hit in the eye by a splinter, and the Court pointed out that the employer should not only have provided the apprentice with protective goggles and instructed him on the exact performance of the work, but should have ensured that the goggles were actually used and the work was performed in accordance with the instructions given, especially since the worker, who was young and had been employed for less than twenty days, was totally inexperienced. *See* also Cass. 17 March 1999, No. 2432.

approach ensures that the workspace is not only aesthetically pleasing, energy-efficient, and comfortable but also meets the employer's health and safety obligations, which extend to the organization of workspaces.[30] This includes, among other considerations, ensuring accessibility for people with reduced mobility, providing clear escape routes, assessing the proximity of workstations to hazardous machinery, etc.

Significant benefits regard also the risk assessment, as confirmed, for example, by the possibility of digitally reproducing with a high level of accuracy 'new' work environments (especially in the construction or service sectors), including by integrating these technologies with the use of drones.

This allows the employer to conduct with the support of the preventive service[31] remote inspections and identify in advance potential hazards before sending employees to start the working activity and reducing their exposure to hazardous conditions.

Nevertheless, these technologies play a crucial role also in managing risks already identified and assessed by the employer. They can enhance real-time employee assistance in daily operations, for instance, by providing AR-driven instructions or camera-based asset identification.[32]

Then, they strengthen employees' ability to respond to emergencies by improving preparedness, reducing response time, and minimizing risks during critical incidents. The added value of these technologies is that they not only enhance situational awareness through realistic simulations but can also provide real-time support during real emergencies. By overlaying critical information — such as evacuation routes, hazard locations, or step-by-step instructions — directly into the worker's visor, they support decision-making under extreme pressure.

Lastly, if properly implemented (by the employer) and used (by the employee), these technologies can also mitigate the risk of isolation for remote workers. This can happen, for example, by creating immersive virtual environments that promote social interactions and live collaboration between employees. By using avatars, virtual spaces, and real-time communication tools, employees can participate in meetings and events, effectively replicating in the virtual realm those social dynamics that typically occur in 'physical' workplaces.

On this specific regard, as the next paragraph will explain, the digital sphere can also reproduce harmful social dynamics to workers' well-being, raising the question of whether the employer bears the same duty of prevention that applies to the social interactions developed in physical workplaces.

[30] *See* article 15, par. 1, letter d) of the Legislative Decree No. 81/2008, which includes among the "general measures of protection" also "compliance with ergonomic principles in the organisation of work, in the design of workplaces, in the choice of equipment and in the definition of work and production methods, particularly to reduce the health effects of monotonous and repetitive work"; see also articles 62-67.
[31] Article 7 of EC Directive 89/391 and Articles 31-35 of the Legislative Decree No. 81/2008.
[32] For example, Shell deploys AR headsets to assist oil rig workers with hands-free, real-time information while performing maintenance in dangerous offshore environments, reducing the risk of errors and accidents, as described at https://jpt.spe.org/shell-deploys-ar-headsets-facilities-12-countries (last access on May 12, 2025).

4. …and risks: the case of "unwanted virtual interactions" and the employer's liability.

Alongside its benefits, integrating XR and Metaverse technologies into the workplace comes with a range of potential risks for employees' health and safety, which can be traced to two macro-categories: the one involving physical-ergonomic risks, and the other including psycho-social risks.[33]

For example, it is possible to attribute to the former category the risks associated with the ergonomic design of head-mounted displays and their prolonged use, which can lead to problems such as cybersickness, eye fatigue, musculoskeletal disorders, and excessive exposure to blue light very close to the user's eyes. The reduced physical movement required during their use, coupled with the possibility of technological malfunction, can exacerbate these risks, as can the immersive nature of such technologies, which increases the risk of accidents caused by employees' spatial disorientation, resulting in slips, trips, and falls. In addition, the repetitive physical interactions required in virtual environments, particularly when coupled with poor ergonomic design, can contribute to repetitive strain injuries, posing long-term health risks.[34]

Less considered, but still critical, is also the biohazard associated with the use of visors frequently shared or worn by more than one worker, which can promote the contamination by pathogens and related infections among employees.[35]

Turning to psychosocial risks, scholars have identified potential problems like overreliance on digital systems, mental fatigue, and cognitive overload, which reduces attention, memory, and spatial awareness. Other risks include acute stress resulting from the need to acquire new skills and adapt to unfamiliar equipment, and technostress.[36] Prolonged immersion in virtual environments may also blur the boundaries between work and personal life. In addition, as previously noted, without careful design and implementation, these technologies may exacerbate – instead of mitigate – the risks of isolation and social detachment of employees.[37]

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[33] *See*: European Agency for Safety and Health at Work (EU-OSHA), *Worker exposure to virtual and augmented reality and metaverse technologies: How much do we know?,* nt. (15), 7; see also Bérastégui P., *Working in the metaverse: What are the risks?*, 8 February 2024, available at www.etui.org/publications/working-metaverse-what-are-risks (last access on May 12, 2025); Valenti C., *La destrutturazione spazio-temporale del lavoro: quali rischi dalle tecnologie immersive?,* nt. (10), 102; Donini A., Novella M., nt. (10), 17; Maio V., nt. (10), 57; Lamberti F., nt. (10), 228.

[34] European Agency for Safety and Health at Work (EU-OSHA), nt. (15), 8.

[35] Creel B., J. Rinz-Jones C., Jones A., Jackson C. R., *Bacterial Load of Virtual Reality Headsets*, in Teather R. J. et Al., *Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology*, Association for Computing Machinery, New York, 2020, 1.

[36] On technostress Ludovico G., *Nuove tecnologie e tutela della salute del lavoratore,* in Ludovico G., Ortega F.F., Nahas T.C. (eds.), *Nuove tecnologie e diritto del lavoro. Un'analisi comparata degli ordinamenti italiano, spagnolo e brasiliano,* Milano University Press, Milan, 2021, 85; see Valenti C., nt. (10), 112 distinguishing between "techno-strain", "techno-anxiety", "techno-overload" and "techno-complexity"; *see* also Pasquarella V., *(Iper)digitalizzazione del Lavoro e technostress Lavoro-correlato: la necessità di un approccio multidisciplinare,* in *Argomenti di Diritto del lavoro,* 1, 2022, 57; Renzi S., *Digitalizzazione del lavoro e rischi psicosociali,* in Del Punta R., Gottardi D., Nunin R., Tiraboschi M. (eds.), *Salute e benessere dei lavoratori: profili giuslavoristici e di relazioni industriali,* Adapt University Press, Bergamo, 2020, 119.

[37] For an overview *see* European Agency for Safety and Health at Work (EU-OSHA), nt. (15), 12.

While all the aforementioned risks, to some extent, are not entirely new, having already affected organizations undergoing digital transformation, there's a completely unheard challenge which deserves particular attention: the assessment and prevention of risks arising from "unwanted interactions" in virtual reality.

As now repeatedly reported in the media,[38] XR and Metaverse technologies may expose their users to misconducts like virtual harassment or cyberbullying perpetrated within the virtual dimension by colleagues or external users (like costumers).[39]

Concerning such conduct, it is therefore crucial to determine whether the employer has a legal duty to assess them and implement appropriate preventive measures, despite their occurrence in a realm – the *virtual* world – which is out of employer's full control.

The answer is not straightforward and raises several issues.

A first problem that would seem to arise is very similar to the one that criminal law scholars are addressing, which would concern the legal classification of these conducts. In particular, it should be established whether a 'virtual' conduct can constitute an offence that traditionally require a 'physical' harm to a person.[40]

From a labour law perspective such a problem is easily overcome considering the broad notion of "health" adopted by the preventive legislation in line with the World Health Organization:[41] "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity".[42]

Given that this definition expands the concept of "health" beyond the mere absence of illness to encompass the psychological and social well-being of workers, it becomes clear that what matters is not so the presence or absence of physical contact, but the potential negative effects of such misconduct on employees' health. Even just a psychological injury may, in fact, be enough to constitute an injury to the worker's health.

However, this conclusion does not automatically mean that the employer has a legal obligation to assess and prevent these specific misconducts. As mentioned, they occur in the virtual reality, a space that the employer does not fully control, unlike traditional physical workplaces (such as factories or offices).

To solve this issue, case law from both civil and common law legal systems offers useful guidance.

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[38] Basu T., *The metaverse has a groping problem already. A woman was sexually harassed on Meta's VR social media platform. She's not the first - and won't be the last*, in *MIT Technology Review*, December 16, 2021, available at www.technologyreview.com/2021/12/16/1042516/the-metaverse-has-a-groping-problem (last access on May 12, 2025); see also *Female avatar sexually assaulted in Meta VR platform, campaigners say,* May 25, 2022, available at www.bbc.com/news/technology-61573661 (last access on May 12, 2025); Sales N. J., *A girl was allegedly raped in the metaverse. Is this the beginning of a dark new future?*, 5 January 2024, available at www.theguardian.com/commentisfree/2024/jan/05/metaverse-sexual-assault-vr-game-online-safety-meta (last access on May 12, 2025).

[39] Bérastégui P., nt. (33); Dwivedi Y. K., *et al.*, nt. (15); Upadhyay U., Kumar A., Sharma G., Gupta B. B., Alhalabi W., Arya V., Chui K. T., *Cyberbullying in the metaverse: A prescriptive perception on global information systems for user protection*, in *Journal of Global Information Management*, 31, 1, 2023, 1-25.

[40] Bellini O., nt. (9), 77.

[41] Larsen L. T., *Not merely the absence of disease: a genealogy of the WHO's positive health definition*, in *History of Humam Science,* 1, 2022, 111; Schramme T., *Health as complete well-being: the WHO definition and beyond*, in *Public Health Ethics*, 3, 2023, 210.

[42] Article 2, par. 1, letter o) of Legislative Decree No. 81/2008.

Courts have ruled that the employer's duty to protect employees' well-being extends beyond the boundaries of the *physical* workplace and must consider also risks from the external environment or the social context in which the employee carries out his performance.

Italian case law, for example, has held employers liable for both physical and psychological harm suffered by employees due to the lack of adequate preventive measures against robberies[43] or kidnappings by terrorist groups.[44]

Similarly, both Italian and British courts have held employers responsible for failing to protect employees from hazards, such as infectious diseases (like malaria), contracted by the employees in environments where the employer sent them to perform their duties.[45]

Therefore, if an employer can be held responsible for risks present in the 'physical' world over which he has no control – such as those arising from criminal activity or infectious diseases – but against which can still take preventive measures (e.g., offering disease prophylaxis, or armed vigilance to deter robbery or kidnapping), by analogy, he should also be obligated to assess and mitigate similar risks in virtual environments.

Moreover, several recent decisions by Italian Supreme Court further burden the employer's position by extending his duty to protect employees' well-being by preventing not only when the "unwanted interaction" goes so far as to integrate actual "harassment" or "mobbing" or again "straining", but even when it simply creates a "stressful socio-occupational context".[46] A situation that, as daily experience testifies, is much more common within organizations of all sizes.

[43] Cass. 13 April 2015, No. 7405; Cass. 28 February 2012, No. 3033; Cass. 11 April 2013, No. 8855.

[44] Cass. 22 March 2002, No. 4129 finds the employer (a firm specialized in geological research) liable for damages suffered by an employee sent to Ethiopia to carry out geological surveys who had fallen victim to kidnapping by a group of guerrillas. Although the employer was aware of the dangerous situation in the area, it did not provide the necessary preventive measures.

[45] Cass. 29 May 1990, No. 5002 finds the employer responsible for the malaria contracted by an employee in Cameroon because he did not prove to have adopted every possible measure to prevent the employee from the infection, even though he knew that such a humid region was the natural "habitat" of the anopheles. Similarly, in the case *Palfrey v Ark Offshore Ltd.,* England and Wales High Court, 2001 an employee, Mr. Palfrey, travelling to West Africa to work on an oil rig contracted a fatal malarial infection. His employer informed him that he did not need to be concerned about the risk of malaria considering the workplace was an oil rig. So, Mr. Palfrey took no anti- malarial medication before or during the trip but during the travel to the oil rig he slept on an island where he was bitten by a mosquito and contracted malaria, which became fatal. The High Court found a failure of the employer to take reasonable care to ensure the safety of the employee because it was supposed to cover also the travel to and from the oil rig.

[46] See Cass. 11 December 2024, No. 31912 stating "this Court (…) attributes a merely sociological value to the notions of mobbing and straining, sanctioning their irrelevance for legal purposes to which what matters is the occurrence of an employer's conduct that proves to be unlawful, even if only by way of fault, since it is liable to allow the maintenance of a stressful environment that is a source of damage to the health of workers, contrary to Article 2087 of the Civil Code, understood as a general obligation to foresee every possible negative consequence of the lack of balance between the work organisation and the staff employed, giving rise to the need to pay attention to all conduct, even in itself not illegitimate but such as to induce discomfort or stress that is manifested in isolation or instead is connected to other non-compliant conduct, contributing to exacerbate the effects and the seriousness of the injury"; previously see Cass. 7 February 2023, No. 3692; for a review of other cases Serra D., *Sullo stress lavorativo rilevante, a differenza del mobbing e dello straining, giuridicamente,* 31 December 2024; Tambasco D., *La "rivoluzione silenziosa" della giurisprudenza, dal mobbing all'ambiente lavorativo stressogeno: l'inizio di un nuovo modo di giudicare?,* 16 November 2024, both available at www.rivistalabor.it.

So, given such conduct certainly constitutes an injury to the employee's health and safety, and considering that the employer is obliged to assess and prevent them, a new issue arises: can the preventive system outlined by EC Directive 391/89 (and in Italy by Legislative Decree No. 81/2008) be considered still adequate to face this new category of risks affecting the virtual world?

5. The preventive approach at stake.

As known, the preventive approach established by EC Directive 89/391 rather than merely responding to workplace accidents and occupational diseases, requires the employer to adopt a proactive strategy aimed at identifying and eliminating risks before they cause harm to employees.[47]

In this perspective, the main pillar of preventive approach in both the Framework Directive and Legislative Decree No. 81/2008, which transposes the Directive, is the risks assessment, which represents the first and fundamental employer's obligation in the field of OSH.

As known, the risk assessment must be "global", considering "all the risks" and covering every aspect related to work,[48] and it must present an "ongoing" content, ensuring preventive measures evolve in response to the evolution of organization, and so of the emerging risks.[49]

As said, this duty reflects the principle of prevention (article 6 of the Framework Directive), defined as "all the steps or measures taken or planned at all stages of work in the undertaking to prevent or reduce occupational risks" (article 3, lett. d, of the Framework Directive). These "steps" include, among the others, the work adaptation to the individual, "especially as regards the design of workplaces, the choice of work equipment and the choice of working and productive methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health" (article 6, lett. d of the Framework Directive); the replacement of dangerous processes by non-dangerous or the less dangerous alternatives (article 6, lett. f, of the Framework Directive); and the development of a "coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment" (article 6, lett. g, of the Framework Directive)

Nonetheless, the preventive system does not exhaust itself with risk assessment alone and the adoption of related protective measures. To ensure the effectiveness of this system, the

[47] Bertocco S., *La sicurezza del lavoratore nelle fonti internazionali del lavoro*, Cedam, Padova, 1995, 27-109; Natullo G., *La tutela dell'ambiente di lavoro*, Utet, Turin, 1995, 209; Montuschi L., *La tutela della salute e la normativa comunitaria: l'esperienza italiana*, in *Rivista Italiana di Diritto del Lavoro*, 4, 1990, 384; focusing on the Italian legislation Pascucci P., *La nuova disciplina della sicurezza sul lavoro del 2008/2009: una rapsodia su novità e conferme*, in *Working Papers di Olympus*, 1, 2011, 9; Lazzari C., *Figure e poteri datoriali nel diritto della sicurezza sul lavoro*, Franco Angeli, Milan, 2015, 52.

[48] European Court of Justice 12 November 1996, C-84/94, *United Kingdom v. Council*; European Court of Justice 14 June 2007, C-127/05, *Commission v. United Kingdom of Great Britain and Northern Ireland*; *see* also Natullo G., *Soggetti e obblighi di prevenzione nel nuovo Codice della sicurezza sui luoghi di lavoro: tra continuità e innovazioni*, in *WP CSDLE "Massimo D'Antona".IT*, 91, 2009, 8.

[49] Article 9, par. 1, of the Framework Directive; article 29 of Legislative Decree No. 81/2008.

employer has also a general duty to "control", either directly or through his staff (such as supervisors), that the preventive measures are observed and all the other actors of the preventive systems fulfil their own OSH obligations.

Herein lies the issue. Both the Framework Directive and the Legislative Decree No. 81/2008 designed this control activity bearing in mind traditional workplaces – such as factories, offices, or construction sites – where work is carried out "in person", and so its control by the employer and supervisors, which are physically present alongside employees.

This physical proximity has led both courts and inspectors to assign a central role to the employer's duty of control, which, in practice, is most often delegated by the employer to his supervisors. In the Italian context this trend is confirmed by the recent reform of the supervisor's role and responsibilities introduced by Legislative Decree No. 146/2021, converted into Law No. 215/2021. The reform not only made the appointment of a supervisor mandatory in all organizations, regardless of the number of employees,[50] but also significantly strengthened his powers and duties. For example, in the light of new Article 19 of Legislative Decree No. 81/2008, the supervisor must suspend the worker who fails to comply with the employer's health and safety instructions, as well as he must suspend the entire working activity under his supervision, if he identifies a 'danger' to the workers' health and safety.

This reform confirms the crucial importance for the good functioning of the preventive system of the supervisor's role, who ensures a "closer" - and therefore more effective - control over workers' activities. Control that, in the absence of such a figure, the employer would hardly be able to personally guarantee.

It is clear, however, that to exercise these powers and fulfil his duties, the supervisor must, of course, be able to directly 'control' the workers while they perform their tasks.

This is not always possible when performance takes place "in person" (in the *analog* dimension). Even more so, it may not always be possible when the work is carried out in a *digital* environment.

Similar considerations can also be applied to another key figure in the prevention system: the workers' safety representative, whose "duty" (and not anymore "right") to control employees has been recently strengthened by a controversial decision from the Italian Supreme Court.[51]

Regardless of whether or not the solution adopted by the Italian Supreme Court is consistent with the Framework Directive, what is relevant for our purposes is that even in this case the control demanded from the worker safety representative requires the "proximity" to workers controlled. Therefore, when performance takes place in a digital

[50] Pascucci P., *La sicurezza sul lavoro alla prova dell'effettività: l'obbligo di individuazione dei preposti,* in *Lavoro Diritti Europa*, 3, 2022, 1, highlights the interpretative problems this duty creates when there is only one worker employed.

[51] Cass. pen. 27 June 2023, No. 38914 provoking a debate among labour law scholars; among others *see* Gragnoli E., *La responsabilità penale del rappresentante dei lavoratori per la sicurezza,* in *Diritto delle Relazioni Industriali*, 2, 2024, 486; Pascucci P., *Per un dibattito sulla responsabilità penale del rappresentante dei lavoratori per la sicurezza*, in *Diritto della Sicurezza sul Lavoro*, 2, 2023, 1; Ingrao A., *Il rappresentante dei lavoratori per la sicurezza. Storia, funzioni e responsabilità penale*, in *Diritto della Sicurezza sul Lavoro*, 2, 2023, 15.

environment, the same problem set forth for the workers' safety representative as for the supervisor also arises.

On the other hand, Courts and Inspectors, at least in Italy, have interpreted the employees' health and safety obligations in a rather lenient manner, despite they are explicitly defined as a key actor of the broader 'prevention system' by both European legislation (Article 13 of the Framework Directive) and Italian law (Article 20 of Legislative Decree No. 81/2008).

Evidence of this trend includes, on one hand, the near-total absence of criminal proceedings against employees for violating the duties listed in Article 20, par. 2, of Legislative Decree No. 81/2008,[52] and, on the other, a rigorous interpretation of the employer's duty of supervision.[53] This interpretation extends it to the point where the employer is expected to consider that an employee, even when fully trained and informed about the risks he faces, may still act negligently and ignore explicit safety instructions. As a consequence, the employer is obligated to set up a system of controls that prevents even such negligence by employees.[54]

The combination of a strict employer's duty to control and the lenient interpretation of employees' duty to collaborate for their own and others' safety can lead to serious distortions when the performance is carried out remotely or, further, within the 'digital realm' through XR headsets or the Metaverse.

The concrete risk is that the liability of the employer and any other actor in a guarantee position could shift to a form of strict liability, with the effect of discourage the adoption of such technologies (and their benefits) in the workplace.

6. "Prevention" demands "participation".

The more lenient interpretation of workers' cooperation duties has traditionally been driven by the aim of ensuring them an higher level of protection. The underlying assumption was as follows: if the employer's duty of supervision is intensified to the point of requiring him to take into account even cases of worker negligence, as a result, the preventive system will be structured in a more pervasive and stringent manner and, so, it will undoubtedly be more effective.

This is a misleading argument.

[52] Article 59 of Legislative Decree No. 81/2008 introduces criminal and administrative sanctions for workers who respectively violate the duties listed in Article 20 paragraph 2 and Article 20 paragraph 3 of the same Decree.

[53] According to Article 18, par. 3 *bis,* of the Legislative Decree No. 81/2008: "The employer and the managers are also obliged to supervise the fulfilment of the obligations under Articles 19, 20, 22, 23, 24 and 25, without prejudice to the exclusive liability of the persons obliged under those Articles if the failure to fulfil those obligations is attributable solely to them and if there is no evidence of a lack of supervision on the part of the employer and the managers."

[54] Among the others, see Cass. pen. 9 May 2017, No. 22613 stating that "the exhaustive training (…) does not, however, exclude the absence of a continuous and pressing control [of the employer] to require workers to comply with safety rules"; for a different position, see Cass. pen. 3 March 2016, No. 8883.

Both the Framework Directive and Legislative Decree No. 81/2008 have instead established a preventive system based on the integrated and proactive participation of all the actors involved in the workplace: not only the employer, who is unquestionably the primary duty-bearer, but also managers, supervisors, workers representatives and the workers themselves.

As demonstrated by the obligations expressly assigned to them, each of these actors is required to play a specific role within the prevention system. Performing this role and fulfilling the obligations associated with it becomes essential to ensure the highest possible level of protection in the workplace.[55]

With specific regard to the employees, under Article 13 of the Framework Directive, they must take reasonable care of their own safety and that of others, following the employer's instructions. They are required, for instance, to correctly use machinery, tools, and protective equipment, avoid tampering with safety devices, and report any serious hazards or deficiencies. Additionally, they must cooperate with the employer and safety representatives to implement protective measures and comply with legal requirements, ensuring a safe working environment within their scope of activity.

The aforementioned Article 20 of Legislative Decree No. 81/2008 supplements and further specifies the obligations outlined in Article 13 of EC Directive 89/391, imposing additional duties on workers. In addition to the general obligation to safeguard their own health and safety, as well as that of others (Article 20, par. 1), and to correctly use work equipment and protective devices, workers are explicitly required to comply with company regulations and safety instructions, refrain from modifying personal protective equipment, participate in mandatory training programs, undergo occupational health surveillance where required, and abstain from any conduct that may compromise workplace safety (Article 20, par. 2).

Such obligations confirm the approach which grounds the highest possible safety level in the workplace on the cooperation of all actors, albeit with varying degrees of responsibility among them.

This consideration allows an answer to the question posed in the previous paragraph. It is clear that, given the diversity of concrete cases and the rhythm of technological evolution, the following answer can only outline a general trend toward which the prevention system should evolve.

Concerning risks that affect the worker's physical sphere, there do not seem to be any substantial differences from the past: the employer remains the first and main responsible for their assessment and prevention since these risks occur in a dimension (the *physical* one) over which the employer can exercise his full control.

[55] By analogy, the functioning of the preventive system could be compared to that of an orchestra: the conductor undoubtedly has the primary and most significant responsibility for the success of the performance, having to coordinate the actions of every member of the orchestra. Individual musicians also play a key role, following the conductor's instructions and diligently performing their assigned parts. The same can be said of the preventive system, where the employer, like the conductor, is primarily responsible for the outcome (ensuring the health and safety of workers), with the task of organizing the preventive system and monitoring its proper implementation. For their part, workers, just like musicians, have specific tasks and are also crucial to achieving the common goal: ensuring the highest possible level of safety at work.

In this regard, it is clear that the technological complexity characterizing XR and the Metaverse requires the employer to rely on the increasingly indispensable advice of his consultants: the occupational physician and the prevention and protection service, both of whom must have specific expertise on these technologies. Therefore, where the implementation of such technologies is planned, it would be advisable to avoid having the employer directly assume the role of manager of the prevention and protection service.[56]

The answer seems to change when considering psychosocial risks, such as those arising from "unwanted virtual interactions" or a stressful virtual environment.

In such cases, it is not always possible for the employer to implement adequate preventive measures (e.g., limiting access to the virtual dimension to specific users or external participants) or to enforce compliance with safety regulations by workers. In addition, when work is done entirely in the *digital* sphere, it currently seems very difficult also to ensure the kind of comprehensive supervision that could be exercised in the *physical* workspace.

These technical difficulties, however, do not absolve the employer from liability for potential damage to workers' health and safety.

Anyway, if a single measure seems unsatisfactory, it is then possible to consider the combined action of several of them.

On the one hand, measures that current technology allows should be implemented. For example, in the case of work performed in the Metaverse, in addition to the employees' education on the right way to interact with the colleagues, the employer should organize employees' tasks to be performed in teams that always include a supervisor, or mechanisms could be introduced that allow workers who experience "unwanted interactions" to immediately alert colleagues present in the *physical* world, allowing them to intervene.

On the other hand, it seems necessary to enhance the role that the worker must play in ensuring the effective functioning of the prevention system. In a context in which continuous vigilance is not structurally feasible (except at the cost of limiting privacy, as will be discussed in the next paragraph), obligations such as the worker's duty to take care of his own health (Article 20, par. 1 of Legislative Decree No. 81/2008) and the duty to report unaddressed risks to the employer should assume particular relevance.

It is important to clarify that this does not involve shifting part of the employer's responsibility to the worker. The employer remains the main responsible for the health and safety of employees. Rather, the goal is to fully implement the pragmatic approach that characterizes both the Framework Directive and Legislative Decree No. 81/2008, which rightly led to abandon the utopia of a "zero-risk workplace."

Considering that there is no completely risk-free workplace, it is not possible to achieve the highest possible level of occupational safety without the participation of all actors in the prevention system, albeit within the limits set by law per each of them.

In other words, the prevention system can only function if it is also "fully participatory".

Following such a view, in the case of work performed in a virtual environment, a worker who experiences unwanted virtual interactions or even a stressful (virtual) work environment is required to immediately report the situation to his managers or supervisors. In case of

[56] *See* Article 34 of Legislative Decree No. 81/2008 and its Annex II.

inaction on the part of superiors, the worker can lawfully exercise his right to "resistance." This right may take the form of immediately stopping work in the virtual environment or refusing to perform it unless specific preventive measures are implemented (e.g., the presence of a supervisor or disciplinary action against the supervisor).[57]

In addition to the workers themselves, the role and prerogatives of other actors should be "updated" to the new *virtual* context.

It is the case of the workers' safety representative. Considering that the Italian Supreme Court has recognized his "duty" (rather than just the "right") to control safety conditions in the workplace and inform the employer about any violation or deficiencies, it could be argued that the right of safety representatives to "access" physical workplaces, as stipulated in Article 50, co. 1, letter a) of Legislative Decree No. 81/2008, should also extend to *virtual* workplaces. If this interpretation were to be adopted, the employer would be obliged to guarantee workers' representatives access to the virtual dimension at all times, providing them with the necessary devices to carry out their functions.

Considering the supervisor, it should be assumed that the activity in the virtual workplace cannot be carried out "in solitude" by a single worker, but he must always work in a team with the supervisor himself. Where this is not possible, it could be considered adequate for the supervisor to have a way to operate control either from the *physical* workplace (e.g., by monitoring the worker's physical parameters) or by scheduling periodic accesses to the *virtual* world.

7. "Full Participation" *vs* continuous monitoring.

Among the various challenges posed by adopting XR technologies and the Metaverse, safeguarding users' privacy emerges as a critical issue. This concern extends to the nature and the vast amount of data being processed by the employer through these technologies.

For example, the creation of digital avatars or the monitoring activity of workers using visors could require collecting biometric and behavioral data, which falls within the scope of Article 9 of the GDPR.[58]

This pervasive and massive processing of biometric data is then encouraged by the severity with which we said the Courts interpret the employer's obligation to control employees. It is clear that if the employer must also assess the negligence of workers, he will be encouraged to implement very strict and pervasive surveillance systems, such as those that in the abstract are allowed by XR technologies and the Metaverse.

In principle, the European legal framework seems to authorize such processing activity when it is justified for reasons of protecting the health and safety of workers.

[57] On the plea of non-performance raised by the worker under Article 1460 of the Italian Civil Code *see*: Ferrante V., *Potere e autotutela nel contratto di lavoro subordinato*, Giappichelli, Turin, 2004; Mattarolo M. G., *Il Dovere di obbedienza*, in Cester C., Mattarolo M. G., *Diligenza ed obbedienza del prestatore di lavoro. Art. 2104*, in Schlesingher P., Busnelli F., Il *Codice Civile. Commentario*, Giuffrè, Milan, 2007, 475 ff.; *see* also Suppiej G., *Il diritto dei lavoratori alla salubrità dell'ambiente*, in *Rivista Italiana di Diritto del Lavoro*, 1988, I, 446.
[58] Bérastégui P., nt. (33); *see* also Peruzzi M., nt. (9), 66.

Clearly, the first legal source to consider is the GDPR.

According to this EU Regulation the employer could process biometric and behavioral data not by relying on the worker's consent (Article 9, par. 2, letter a) of the GDPR), which is often considered unsuitable in the employment context due to the power imbalance between the parties, but rather on alternative legal grounds.[59] These may include the necessity to fulfil contractual obligations (Article 9, par. 2, letter b) of the GDPR) or the pursuit of occupational health and safety objectives, such as evaluating the worker's capacity to work (Article 9, par. 2, letter h) of the GDPR).

The GDPR, therefore, seems to allow employers to process health-related data of workers to prevent accidents and, more broadly, ensure workplace health and safety, even without the workers' consent, as long as it complies with the general principles laid out in Article 5.

No limits seem to arise even from the recent EU Regulation 2024/1689 (the so called "AI Act"), which comes into consideration since many of these technologies are based or integrated with AI systems.[60]

Provided that the current regulatory framework does not place appreciable limits on the introduction of these strict monitoring systems, when justified by reasons of health and safety protection, it cannot be denied that such processing could prove highly effective in addressing the issue of "unwanted virtual interactions" previously discussed - an issue that, as noted, is particularly challenging to manage through traditional workplace monitoring mechanisms.

Consider, for instance, the case of a worker who experiences virtual harassment, resulting in significant alterations to his biometric parameters (such as eye movements, facial expressions, gestures, and physiological responses). Continuous monitoring of these parameters would allow the employer to automatically and in real-time detect the worker's distress and promptly implement remedial measures (e.g., supervisor intervention, worker disconnection, etc.). This method would undoubtedly be effective, not least because it circumvents the limitations inherent in human oversight.

However, as mentioned above, the "price" the worker must pay for his own health and safety is a substantial sacrifice of his individual sphere.

Even if limited in its purpose (to ensure OHS protection) and compliant with the principles set out in Article 5 of the GDPR, it nonetheless constitutes a significant intrusion

[59] *See*: Topo A., Tardivo D., *Hard law e soft law nel Diritto dell'Unione europea in materia di trattamento dei dati personali e di tutela della riservatezza del lavoratore*, in Proia G., Pisani C., Topo A. (eds.), *Privacy e lavoro. La circolazione dei dati personali e i controlli nel rapporto di lavoro*, Giuffré, Milan, 2022, 75-109.

[60] Article 5, par. 1, letter f), of the AI Act leads to the category of "unacceptable risk" and thus bans the introduction on the market or use of AI systems designed to infer emotions from a natural person in the workplace or educational institutions, except where the use is intended for medical or safety reasons. This rule must be interpreted in the light of Recital 18 of the AI Act, which states: "the notion of 'emotion recognition system' referred to in this Regulation should be defined as an AI system for the purpose of identifying or inferring emotions or intentions of natural persons on the basis of their biometric data. The notion refers to emotions or intentions such as happiness, sadness, anger, surprise, disgust, embarrassment, excitement, shame, contempt, satisfaction and amusement. It does not include physical states, such as pain or fatigue, including, for example, systems used in detecting the state of fatigue of professional pilots or drivers for the purpose of preventing accidents". For further considerations on this topic *see* European Commission, *Guidelines on the definition of an artificial intelligence system established by Regulation (EU) 2024/1689* of February 4, 2025; Peruzzi M., *Intelligenza artificiale e Lavoro. Uno studio su poteri datoriali e tecniche di tutela,* Giappichelli, Turin, 2023.

into the worker's privacy which may also expose him to potentially discriminatory conduct difficult to contrast. It could happen, for instance, that the employer - in violation of the general processing principles laid down in Article 5 of the GDPR - decides to secretly aggregate the data collected through such technologies and thus obtain an overview of the physical condition or of the behaviour of the employee, and then discriminate against him on account of his health condition.

This raises the question of whether the implementation of an effective and fully participatory prevention system could serve as a valuable alternative to such invasive surveillance system, especially considering that, while the latter may appear lawful under GDPR and AI Act principles, it could nonetheless expose workers not only to the risk of discrimination but also further risks such as to stress, anxiety, tension, or psychological distress stemming from the awareness of being under constant monitoring, even if solely for their own safety.

For the future, it seems, therefore, preferable to take the path of a "fully participatory" prevention system rather than the path of "continuous control".

8. Final remarks.

The brief analysis carried out has highlighted how the use of XR technologies and the Metaverse in the workplaces presents truly significant opportunities for occupational health and safety, particularly in terms of training, risk assessment, and emergency management. These technologies, therefore, should certainly gain traction within the framework of prevention systems.

However, similarly, such technologies also pose various risks to workers' health and safety, some of which are already familiar to businesses due to their connection to the digitalization of processes, while others are entirely new, such as the case of "unwanted virtual interactions."

The implementation of these technologies must, therefore, be accompanied by effective risk prevention strategies, which cannot be limited to mere risk assessments and the adoption of corresponding preventive measures, no matter how technologically advanced they may be.

What is needed is a paradigm shift, or more precisely, a full realization of the "participatory" preventive approach that the Framework Directive outlined as early as 1989, wherein every actor in the prevention system is called, within the scope of their role, to collaborate to achieve the highest possible level of safety.

What is being emphasized here is not a definitive conclusion or a specific set of measures to govern the introduction of these technologies in the workplace, but rather a "method" that must be adapted to each organization and each specific technology.

The participatory method, despite being almost forty years old and having been conceived in a historical period with technology far removed from its current level, remains extraordinarily relevant today.

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