

Implementing Immersive and Biometric Technologies to Prevent Psychosocial Risks in Industrial Settings: Evidence-Based Guidance for Occupational Health and Safety

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Preventing psychosocial risks in industrial environments, such as occupational stress, burnout, and harassment, remains a challenge for Occupational Health and Safety (OHS) teams and organizational management. This study synthesizes consolidated evidence on how virtual reality (VR), augmented reality (AR), and biometric technologies (wearables, biofeedback, and eye tracking) can be used by organizations to prevent and mitigate psychosocial risks, aiming for healthier work environments aligned with OHS practices, standards, and current laws. An umbrella review was conducted, following the PRISMA guidelines, focusing on studies from the last five years that used immersive technologies and physiological sensors in organizational contexts. The analysis highlighted significant interventions for industrial training and prevention programs, such as the use of scenarios for the development of socio-emotional skills and the objective monitoring of stress-related responses. Evidence shows that immersive experiences can safely replicate situations of escalating conflict and abusive behavior, while biofeedback and eye tracking provide complementary, near real-time information on cognitive and emotional overload. When combined, these strategies aid in the early detection of psychological distress and allow for more focused and personalized interventions. As a practical contribution, the results guide industry-oriented design decisions towards applicable solutions, indicating what should be simulated, measured, and how to translate these results into actions to mitigate psychosocial risks. This strengthens preventive strategies, training effectiveness, and continuous improvement in the management of these risks. Future research should prioritize empirical validation in industrial contexts, cost-benefit assessments, and feasibility for large-scale implementation.

Keywords: Virtual Reality. Psychosocial Risks. NR-01. Biometric Sensors. Mental Health at Work.

With growing global concern about psychosocial risks in the workplace, Occupational Health and Safety (OHS) regulations have undergone significant changes. In 2019, the WHO estimated that 15% of the working-age population suffered from a mental disorder, with depression and anxiety leading to 12 billion lost workdays annually, costing the global economy US\$1 trillion [1]. These risks are intrinsically linked to work practices, environments, and interpersonal relationships, contributing to anxiety, depression, chronic stress, insomnia, and even suicide attempts [2]. In Brazil, Regulatory Standard No. 5

(NR-05), updated in 2022, requires organizations with an Internal Commission for the Prevention of Accidents and Harassment (CIPA) to adopt measures against harassment and workplace violence [3]. Regulatory Standard No. 1 (NR 01), updated in 2024, mandates the identification, assessment, and control of psychosocial risks in the Risk Management Program (PGR) [4]. Internationally, ISO 45003:2021 offers guidelines for managing psychosocial risks, including prevention, intervention, and rehabilitation [5].

ILO estimates indicate that 1 in 5 workers worldwide (23%) have experienced violence or harassment at work, though underreporting remains high [6]. In Brazil, data from the Occupational Health and Safety Observatory show that between 2019 and 2024, mental and behavioral disorders ranked third among causes of both occupational and non-occupational leave. For occupational origin (B91), these accounted for 6.17%, and for

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non-occupational origin (B31), 12.5%. Combined (B91+B31), benefits granted due to mental health conditions more than doubled, from 224,647 in 2019 to 471,649 in 2024. The main causes were anxiety disorders, severe stress reactions, adjustment disorders, and depressive episodes. According to the Brazilian Classification of Occupations (CBO), the occupation most affected by non-occupational mental health leave (B31) was “production line feeder,” representing 3.16% of cases (48,530 leave requests) [7].

In response, innovative technologies such as virtual reality (VR) and augmented reality (AR) have been used in immersive training to address harassment, neglect, and hierarchical pressure, fostering socioemotional skills like empathy, self control, and ethical decision-making [8–10]. Eye tracking and biometric sensors, including heart rate variability (HRV) and galvanic skin response (GSR), enable real-time assessment of stress, attention, and emotional discomfort [11,12].

Industry 4.0 has further integrated these technologies into production, allowing the collection and analysis of physiological and behavioral data for preventive, personalized interventions [13]. With rising mental health concerns, these tools also facilitate early detection of psychological distress and promote inclusive, evidence-based practices [14]. However, there is still limited research combining VR, AR, eye tracking, biometric sensors, and biofeedback for psychosocial risk mitigation within regulatory frameworks.

This study aims to provide evidence-based guidance for Occupational Health and Safety by synthesizing consolidated evidence on how immersive and biometric technologies can be implemented to prevent and mitigate psychosocial risks in industrial environments.

Materials and Methods

This study is exploratory in nature, as investigations into the combined use of immersive and biometric technologies in the management of

psychosocial risks in the workplace still represent an emerging and constantly evolving field. Therefore, a qualitative approach was chosen, which is suitable for studies in underexplored areas that require in-depth interpretative analysis [15].

In order to consolidate existing knowledge in the scientific literature, an umbrella review was conducted with the following objectives: (i) to identify studies addressing the application of technologies such as virtual reality, augmented reality, biometric sensors, and eye tracking in organizational contexts; (ii) to analyze the evidence regarding the effectiveness of these technologies in preventing and mitigating psychosocial risks in industrial environments; (iii) to verify the alignment of these interventions with the guidelines of NR-01 and ISO 45003 standards; and (iv) to propose recommendations for the development of technological solutions aimed at promoting mental health in the workplace.

To ensure transparency, methodological rigor, and reproducibility, the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was adopted [16]. The review followed established methodological guidelines and structured the process into four main stages: planning, search, analysis of the evidence base, and synthesis of results. The following subsections describe each step adopted in this study.

Planning

The planning stage involved defining the thematic scope of the research and selecting relevant scientific databases to ensure the breadth and quality of the sources consulted. The search was conducted in the Scopus, PubMed, and Web of Science databases, chosen for their broad international coverage, peer-reviewed content, and strong citation metrics, making them suitable for systematic reviews in interdisciplinary fields [17]. Google Scholar was used as a complementary source to broaden the identification of relevant studies and track cited references. The focus was

on identifying secondary studies investigating the application of immersive and biometric technologies in mitigating psychosocial risks in occupational settings. The methodological protocol was prepared in advance and submitted for review by experts in the fields of virtual reality, workplace mental health, and systematic review, ensuring conceptual alignment and scientific rigor.

Literature Search

A comprehensive search was conducted using a structured search string aligned with the research question, targeting the databases identified during the planning phase [17]. The following descriptors and Boolean combinations were used: ("realidade virtual" OR "virtual reality") AND ("realidade aumentada" OR "augmented reality") AND ("rastreamento ocular" OR "eye tracking") AND ("sensores biométricos" OR "biometric sensors") AND ("riscos psicossociais" OR "psychosocial risks") AND ("revisão sistemática" OR "systematic review") AND "biofeedback". Only peer reviewed articles published between 2019 and 2024 were considered. For methodological and theoretical grounding, additional relevant sources were also included regardless of publication year. The results were exported to spreadsheets, where records were organized and initially screened.

Evidence Base Assessment

In this stage, the previously defined eligibility criteria were applied. Included were systematic reviews or meta-analyses that presented interventions based on VR, AR, biometric sensors, or eye tracking, provided they were applied in occupational contexts focused on mental health or psychosocial risks. Excluded were narrative reviews, conceptual or exploratory studies, and articles that did not directly address the context of workplace mental health.

Initially, 312 records were identified. After removing 87 duplicates, 225 articles remained

for title and abstract screening. In this stage, 183 records were excluded for not meeting the eligibility criteria. The remaining 42 articles were read in full, resulting in the inclusion of 10 systematic reviews, 2 national regulatory standards (NR-01 and NR-05), and 1 international standard (ISO 45003). To enrich the scientific evidence base of this review, additional secondary sources were included, such as specialized book chapters and recognized institutional platforms. Specific book chapters were used to deepen the methodological approach related to the integration of biofeedback with immersive technologies, biosensors, and user perception. Furthermore, statistical data and indicators were obtained from official and updated sources, including the Occupational Health and Safety Observatory of the SmartLab MPT-ILO platform, as well as reports from the International Labour Organization (ILO) and the World Health Organization (WHO). The use of these sources aims to enrich the understanding of psychosocial risks by aligning empirical data with the theoretical analysis presented in this study.

Synthesis and Analysis of Results

The results were organized in a spreadsheet containing the following information: author/year, type of technology used (VR, AR, biometric sensors, eye tracking), psychosocial topic addressed, application sector, type of review (narrative or meta-analysis), and main findings. The information was systematized into thematic categories to facilitate qualitative analysis of patterns, gaps, and recommendations found in the selected reviews.

Results and Discussion

This section presents the main findings of the umbrella review, emphasizing their implications for practical implementation in industrial Occupational Health and Safety contexts. The results are discussed based on evidence extracted from the systematic reviews analyzed, with a focus

on the practical application of these tools across different industrial sectors, the psychosocial variables investigated, the methodologies adopted, and the challenges associated with their implementation.

Immersive and Biometric Technologies: State of the Art and Applications

Virtual reality remains the most prominent technology, widely used in immersive training to simulate complex situations, foster empathy, and address sensitive ethical issues [8,9,18]. Augmented reality is often employed to reinforce training and safety regulations, including in on site environments [10,18]. Biometric devices such as HRV and GSR use biofeedback techniques to monitor stress levels in real time, while eye tracking helps identify behavioral patterns related to attention and emotional shifts [11,12].

The combined use of biofeedback with these technologies enables objective evaluation of the user's experience in immersive environments. In addition to measuring stress levels, engagement, emotional discomfort, and fatigue during training and simulations, these devices provide additional parameters for validating scenario effectiveness and tailoring interventions. For example, visual avoidance behaviors detected through eye tracking may be associated with greater personal discomfort, suggesting their potential as early indicators of emotional distress. Integrating this information into analytical platforms allows for individualized interventions and reports that anticipate trends, supporting decision-making in Occupational Health and Safety (OHS) and Human Resources Management [19].

Psychosocial Focus, Evaluated Variables, and Application Contexts

The main variables investigated included harassment perception, empathy, workplace stress, emotional self-regulation, anxiety, burnout, and attentional deviation. These technologies

enabled objective and personalized assessment and intervention on these factors [8–11, 18].

Although most studies focused on clinical and educational settings, there has been growing research in industrial environments such as logistics, continuous manufacturing, and heavy engineering [10,18]. Case studies in the automotive and construction industries indicate reduced anxiety, improved communication, and greater adherence to safety protocols after immersive training.

Methodological Synthesis of Systematic Reviews

The reviews included provided narrative summaries or quantitative meta-analyses using validated psychometric scales and PRISMA guidelines. Main challenges were the lack of long term data, limited sample diversity, and replication difficulties across industrial sectors. Methodological differences among reviews hinder result comparisons. Some applied the AMSTAR 2 checklist for rigor, while others did not clearly state inclusion and exclusion criteria.

There is a growing number of interdisciplinary reviews combining occupational health and behavioral sciences, highlighting the complexity of psychosocial risks and the need for integrated solutions.

Challenges and Perspectives on Technology Adoption

The use of immersive and biometric technologies to prevent psychosocial risks in industry is growing despite ongoing obstacles. VR and AR effectively promote empathy, emotional intelligence, and address workplace harassment and stress, enabling safe exposure to adverse situations and ethical reflection.

Biometric sensors (HRV, GSR, respiratory monitoring, eye tracking) offer precise emotional and fatigue monitoring, supporting evidence based interventions aligned with standards like NR-01 and ISO 45003.

Challenges include high costs, infrastructure needs, training, and integration with OHS systems requiring standardized solutions. Ethical concerns over data privacy, consent, and security also affect acceptance.

Longitudinal studies are lacking, limiting generalization, and methodological issues like sensor calibration and data privacy need resolution to standardize biofeedback in OHS.

Cultural resistance and fears of surveillance persist, but transparent communication and employee involvement foster trust and innovation. Ethics committees and dialogue forums help align practices with local contexts.

Despite difficulties, VR, AR, biometric sensors, and biofeedback trends point to personalized, data-driven psychosocial risk management.

Collaboration among science, technology, management, and policy, with partnerships and research investment, is vital to prioritize workplace mental health responsibly.

Table 1 provides a practical mapping between immersive and biometric technologies, specific psychosocial risks, measurable indicators, and outcomes for decision-making in Occupational Health and Safety (OHS) and Human Resources

(HR), translating the analyzed evidence into practical guidance for industry stakeholders. This mapping aligns technological applications with the regulatory requirements of NR-01 and ISO 45003 standards, facilitating implementation in industrial environments.

Minimum viable pilot project in an industrial context (6 to 8 weeks):

- Establish the priority psychosocial risk based on the PGR (NR-01).
- Choose the type of situation (harassment, pressure, conflict, high-demand task).
- Select the degree of monitoring (none → wearable → wearable + eye tracking).
- Ensure informed consent and data governance (privacy, access and retention).
- Use baseline and post-intervention metrics (a validated scale + an objective indicator).
- Establish the decision standard for intervention or referral.
- Communicate the results to the OHS committee and the CIPA.

From a regulatory perspective, the incorporation of immersive and biometric technologies directly

Table 1. Actionable mapping: Technology → Psychosocial risk goal → Measurement → OHS/HR decision.

Technology	Psychosocial Risk Target	Practical Metric	Output for OHS / HR	Regulatory Alignment
VR / AR immersive scenarios	Harassment prevention, ethical conflict, empathy	Scenario performance, validated self-report scales	Targeted training, behavioral feedback	NR-01 (risk identification), ISO 45003 (prevention)
HRV / GSR (biofeedback)	Stress, anxiety, emotional overload	HRV indices, EDA peaks	Early risk flagging, referral criteria	NR-01 (risk monitoring)
Eye tracking	Emotional discomfort, attentional avoidance	Gaze fixation, avoidance patterns	Training adaptation, scenario redesign	ISO 45003 (work design)
Integrated biofeedback platforms	Burnout, emotional dysregulation	Physiological trends across sessions	Personalized intervention plans	NR-01 + ISO 45003

facilitates the workflow established by NR-01, especially in the phases of identification, assessment, and control of psychosocial risks within the Risk Management Program (PGR). Simulated scenarios and biometric monitoring assist in the proactive identification of risks, while interventions based on biofeedback favor constant monitoring and prevention. At the same time, ISO 45003 highlights a cyclical approach to the management of psychosocial risks, encompassing job design, leadership practices, and employee engagement. The technological applications synthesized in this review are in line with these guidelines, allowing for evidence-based interventions, constant feedback, and organizational learning, as demonstrated in the mapping presented in Table 1.

From an industrial implementation perspective, pilot programs using these technologies can track practical key performance indicators (KPIs) such as: (i) a decrease in reported psychosocial incidents or an improvement in the quality of reports; (ii) changes in scores on validated stress or burnout scales before and after the intervention; (iii) training completion rates associated with behavioral indicators observed during the scenarios; and (iv) physiological patterns that signal reduced stress reactivity in repeated sessions.

The adoption of immersive and biometric technologies in the workplace still depends on ethical considerations. To ensure that physiological and behavioral data is collected solely to promote health and prevent risks, it is essential to adopt principles such as data minimization and purpose limitation. To preserve trust, transparent governance, restricted access, and well-defined data retention policies are fundamental. Furthermore, employee participation in scenario creation and the provision of clear feedback reports on collective results can reduce feelings of monitoring and encourage the acceptance of these technologies as supportive rather than punitive tools.

Conclusion

This umbrella review provides evidence-based guidance showing that integrating immersive

technologies (VR, AR) with biometric sensors and eye tracking offers promising solutions to prevent psychosocial risks in industrial workplaces. Recent studies highlight their role in identifying, assessing, and intervening in harassment, stress, anxiety, and burnout, promoting healthier and more inclusive work environments [9,18,20].

VR and AR training simulate critical situations and develop socio-emotional skills like empathy and ethical decision-making in safe settings. Biometric sensors and eye tracking provide real time, objective data on workers' emotional states, enabling early psychological distress detection and personalized interventions [8,10,11].

Challenges for wide adoption include costs, infrastructure, training, data privacy, and adapting solutions to diverse industrial and cultural contexts. Longitudinal studies and real-world protocol validations are lacking, especially in developing countries [18,20].

These technologies align with NR-01 and ISO 45003 standards, supporting occupational health and safety and fostering organizational cultures open to mental health dialogue. Expected benefits include reduced harassment, improved well being and productivity, and enhanced data-driven decision-making [18,20].

Recommendations include investing in applied research, longitudinal monitoring, standardizing protocols for VR, AR, biometric and eye tracking tools, ongoing professional training, and adapting to laws and organizational policies. Public policies should encourage pilot projects and partnerships among academia, industry, and regulators for ethical and technical viability.

Biofeedback combining biometric sensors and eye tracking advances objective user experience assessment, measuring stress and engagement in real time for personalized interventions. Methodological challenges remain, such as sensor calibration, privacy, consent, and industrial context adaptation to establish biofeedback in OHS and psychosocial risk prevention [19].

In summary, these technologies meet regulatory demands and can transform organizational culture,

creating safer, healthier, and more innovative workplaces benefiting employees, companies, and society.

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