Prevention of Psychosocial Risks with Immersive and Biometric Technologies in Industry: A Systematic Review

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Abstract: The prevention of psychosocial risks in the industrial context, such as occupational stress and harassment, still represents a challenge for the promotion of healthy work environments. This study aims to understand, based on consolidated evidence, how immersive and biometric technologies can contribute to the prevention and mitigation of these risks, promoting safer, more humanized environments aligned with current regulations. A systematic review was conducted following PRISMA guidelines, focusing on studies from the last five years that applied virtual reality, augmented reality, biometric sensors, and eye tracking in organizational settings. The analysis focused on interventions aimed at promoting mental health and preventing abusive behaviors in industrial environments. The results indicate that these technologies enable the simulation of critical scenarios for the development of socioemotional skills and offer objective real-time data on workers' emotional states. The use of biofeedback, integrating physiological variables and eye tracking, proved effective in the early identification of psychological distress and in guiding personalized interventions. The integration of these technologies can strengthen institutional strategies for occupational health and safety, expanding the preventive and educational reach of actions. The study provides support for the development of technological solutions applicable to professional training and the promotion of safer environments. Future research should further explore the empirical validation of these approaches and their feasibility for large-scale implementation.

Keywords: Virtual reality. Psychosocial risks. NR-01. Biometric sensors. Mental health at work. *Candida albicans*)

1. Introduction

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 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 examine, based on consolidated evidence, how immersive and biometric technologies can prevent and mitigate psychosocial risks in industrial environments, fostering safer and more humanized workplaces aligned with current regulations.

2. 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.

2.1. 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.

2.2. 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.

2.3. Evidence base assessment

In this stage, the previously defined eligibility criteria were applied. Included were systematic reviews or meta-analyses that presented interven-

tions 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.

2.4. 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.

3. Results and discussion

This section presents the main findings of the umbrella review, organized into thematic categories that reflect the current state of the literature on the use of immersive and biometric technologies in managing psychosocial risks in the workplace. 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.

3.1. 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].

3.2. 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.

3.3. 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.

3.4. 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.

4. Conclusion

This systematic review shows 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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