Interventions based on biofeedback systems to improve workers' psychological well-being, mental health and safety: a systematic literature review

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Abstract

Background: In modern, high-speed work settings, the significance of mental health disorders is increasingly acknowledged as a pressing health issue, with potential adverse consequences for organizations, including reduced productivity and increased absenteeism. Over the past few years, various mental health management solutions, such as biofeedback applications, have surfaced as promising avenues to improve employees' mental well-being.

Objective: To gain deeper insights into the suitability and effectiveness of employing biofeedback-based mental health interventions in real-world workplace settings, given that most research has predominantly been conducted within controlled laboratory conditions.

Methods: A systematic review was conducted to identify studies that used biofeedback interventions in workplace settings. The review focused on traditional biofeedback, mindfulness, app-directed interventions, immersive scenarios, and in-depth physiological data presentation.

Results: The review identified nine studies employing biofeedback interventions in the workplace. Breathing techniques showed great promise in decreasing stress and physiological parameters, especially when coupled with visual and/or auditory cues.

Conclusions: Future research should focus on developing and implementing interventions to improve well-being and mental health in the workplace, with the goal of creating safer and healthier work environments and contributing to the sustainability of organizations.

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Review

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Keywords: biofeedback; well-being; mental health; breathing techniques; occupational safety; occupational health

Introduction

In today's fast-paced and demanding work environments, the impact of mental health disorders is gaining widespread recognition as a critical health concern and can portrait detrimental effects on organizations (1). The effects on organizations are far-reaching, extending beyond individual well-being, decreasing productivity, and heightening absenteeism (2, 3). Extensive literature supports the link between occupational stress, psychosocial factors, and an increased risk of depression, as well as alcohol and drug consumption. It is as if work-related stress acts as a domino effect, setting off a chain reaction of negative consequences. Heavy workloads pile up, leaving employees drowning in a sea of tasks. Job satisfaction plummets, contributing to lackluster performance and a feeling of being physically present but mentally absent, also known as "presenteeism." With stress lurking in the background, accidents and injuries become more frequent, turning the workplace into a potential danger zone. (4-7). According to the OECD/EU (8), mental health problems, such as stress, anxiety, and depression, affect about 84 million people in the EU, with 1 in 4 workers reporting exposure to risk factors that can negatively affect mental well-being. In 2022, the same report portrays a scenario where one in two young Europeans reported unmet needs for mental health care in spring 2022 (9). In view of this, the European Union (EU) Strategic Framework on Health and Safety at Work 2021-2027 adopted by the European Commission reinforces the fight against psychosocial risks (10). It is of paramount importance to face these challenges, by designing and implementing interventions that target the promotion of good mental practices and preventing illness (11). According to the

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Organization for Economic Co-operation and Development (OECD/EU), mental health problems, such as stress, anxiety, and depression, affect about 84 million people in the EU, with 1 in 4 workers reporting exposure to risk factors that can negatively affect mental well-being. In 2022, the same report portrays a scenario where one in two young Europeans reported unmet needs for mental health care in spring 2022. In view of this, they developed a Strategic Framework on Health and Safety at Work 2021-2027 adopted It is of paramount importance to face.

Over the last decades, different solutions for mental health management in occupational settings have arisen during the last decades, such as Cognitive Behaviour Therapy (12-14), Stress/Coping/Mindfulness training (15-17), Problem Solving (18, 19), Acceptance and Commitment Training (20, 21), amongst others. In the same pace, there has been a surge in the introduction of new solutions designed to monitor and improve employee's mental health (22, 23), such as biofeedback applications (24).

Biofeedback emerges as a therapeutic technique aimed at facilitating the acquisition of skills in controlling a diverse range of physiological processes, encompassing muscle tension, heart rate, stress levels, and brain wave activity, thereby fostering enhancements in mental health and overall well-being (25). This methodology employs electronic apparatuses to gauge and present physiological responses, including muscle activity, skin temperature, heart rate, and brain wave patterns, which serve as feedback to guide individuals towards deliberate and purposeful alterations in their bodily functions (26). Within a conventional biofeedback session, an individual is connected to sensors that monitor specific physiological responses, and the ensuing data is instantaneously visualized on a computer screen, granting valuable insights into their bodily reactions while enabling conscious adaptations to ameliorate their well-being (27). For instance, if an individual encounters heightened stress levels, the biofeedback session could potentially expose an augmented heart rate and muscle tension, thus furnishing the subject with actionable information to consciously induce muscle relaxation and regulate their breath, ultimately reducing stress levels (28, 29).

Despite the increasing popularity of physiological monitoring technologies such as Electroencephalography, eye-tracking, and biosensing for fatigue (30) and stress management in occupational settings, biofeedback offers a distinct approach (31-33). While physiological monitoring technologies passively measure and track bodily signals, biofeedback actively engages the individual, using real-time feedback to enable self-regulation of physiological responses (29, 34, 35). This unique characteristic of biofeedback—facilitating the conscious control of bodily processes—differentiates it from passive monitoring techniques.

In this context, biofeedback serves not only as a tool for measurement but as an intervention aimed at improving mental health and well-being through active participation. This process is particularly valuable in occupational settings, where employees can be empowered to manage stress, anxiety, and other mental health challenges through real-time adjustments to physiological responses such as heart rate, muscle tension, and respiration (36).

Wearable devices are used in several biofeedback scenarios such as rehabilitation for providing biofeedback on biomechanical or physiological body parameters, holding promise in enhancing outcomes for individuals (37). However, there remains a need to establish the prevalent sensor configurations commonly employed and to determine the specific biofeedback components utilized for various pathologies (38, 39). For areas such as Monitoring Stress, and Sleep companies in the health and performance technology sector to establish a competitive edge, it is crucial to engage with consumers and identify genuine real-world needs. Additionally, investing in rigorous research to substantiate the effectiveness of their products is paramount. On the other hand, consumers seeking optimal value should exercise care when selecting such products, considering both their personal requirements and the strength of supporting evidence regarding product effectiveness. By aligning these considerations, both companies and consumers can contribute to the advancement and adoption of impactful health and performance technologies. (40)

While there is some evidence about the effectiveness of biofeedback-based interventions with different populations, we must carefully address the traditional laboratory application of biofeedback techniques in real-world applications. Argent et al. (2021) published a use case about the relevance of Real-World Validation of Systems using Wearable Exercise Biofeedback Platforms, exactly pointing that differences between laboratorial environment and real-world settings should be carefully addressed (41). While this case study is specifically for Machine Learning, the authors emphasised the need to map and understand results of biofeedback systems in previous studies developed in real-world environment and occupational settings, as well as the methodology used. However, as far as we know, there is no systematic literature review of the feasibility and effectivity of biofeedback-based mental health management tools and interventions involving workers of different occupational settings. Ter Harmsel et al. (2021) analysed the feasibility of bio cueing and ambulatory biofeedback in the treatment of emotion regulation difficulties, in psychiatric and non-psychiatric populations; no special focus on occupational settings was given in this research (42). Yu et al. (2018) developed a systematic literature review on biofeedback applications for non-medical stress management, with also no special focus in occupational settings (43). Kennedy and Parker (2019) conducted a systematic review of biofeedback on real-time stress management intervention, limiting it to research that included biofeedback administered during the task; however, studies included were not limited to employees (44). None of these previous reviews have delve deeply in analysing, content, and quality of the interventions.

This systematic review aims to identify and analyse interventions based on biofeedback that were specifically designed to improve employee psychological well-being and mental health that were tested in working settings. Our review focuses specifically on biofeedback as a self-regulation tool, distinct from other technologies, and its application within occupational safety and mental health management.

As biofeedback interventions are increasingly explored in other fields, we aim to fill the gap in literature by systematically reviewing biofeedback-based interventions specifically designed for occupational settings for the purpose of improving employee mental health and psychological well-being, with the goal of understanding their effectiveness and potential to enhance workplace safety. Results will be also discussed portraying potential features related to higher engagement, adherence and improve workspace safety.

Methods

Eligibility Criteria

This systematic review was focused on studies in which biofeedback interventions aimed to employees/workers as the targeted population. Both experimental and pilot studies involving a range of mental health disorders that could be addressed using biofeedback were considered. Studies also included a description of interventions aimed at preventing mental health disorders and improving well-being. Having in mind the novelty of the proposed research area, this review aimed to be as inclusive as possible, including experimental and observational studies. However, these studies had to be original and published in scientific peer-reviewed journals.

Studies were excluded regarding the following conditions: 1) use of other sample than employees; 2) studies without a description of the intervention; 3) literature reviews, commentaries, or editorials; 4) studies with a poor methodology assessment in the PEDro checklist (**Supplementary Table 1**).7

Information sources and Search Strategy

The present systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (45). On March 11, 20224 the search for relevant articles published in the last ten years (2012-2024) was conducted through independent searches in selected electronic databases: Science Direct, PubMed, b.on EBSCO.

The search focused on identifying articles that included keywords under the following general categories: Mental health, Biofeedback and Workplace. The keywords used for the search are described in Table 1. The search combined the different keywords and Boolean terms and, was limited to papers published in English in the last ten years.

#Insert Table 1 here#

Data collection process

Search results were exported to EndNote® 20 software for screening. After removing duplicates, two authors, independently, reviewed the title and abstracts in order to identify eligible studies against the specified inclusion and exclusion criteria. Full texts of articles were then analyzed, and conflicts resolved through consensus. Some disagreements between reviewers at each stage of the selection process were solved through discussion and brief meetings. Finally, the results of the search and the study inclusion process are reported in full in the PRISMA flow diagram (**Figure 1**), as well as the reasons for papers exclusion.

Data extraction was performed on the final identified studies and included: (1) citation details; (2) country; (3) intervention groups; (4) obtained measures (Questionnaires and Physiological data collected); (5) intervention description; (6) results; (7) Follow up.

Assessment of Methodological Quality

The quality and bias of all identified studies was assessed. To this end, a list of assessment criteria was constructed using the PEDro checklist (46). Two authors, independently, assessed and rated each study in relation to methodological rigor, selection and reporting bias. Eligible studies were critically appraised by two independent reviewers.

Visualization of Biofeedback publications

VOSviewer (47) was employed for graphical analysis and visualization of the dataset. Keywords were utilized to extract relevant topics from the dataset. The software's Visualization Of Similarities mapping and clustering methods facilitated the creation of a two-dimensional map, delineating the topics in terms of frequency, relatedness, and clustering. The representation of each topic was determined by its frequency of occurrence, visualized by the size of nodes and labels. Distinct clusters were formed and differentiated by color for clear visualization (48).

Results

Search Results

A total of 2363 articles were screened regarding the title only, being left 273 possible candidate publications. After reviewing the abstracts, a total of 33 studies initially seemed relevant for the final content examination. However, following the full-text retrieval and data extraction process, in accordance with the PRISMA flowchart's criteria for relevance, the number of studies pertinent for analysis was narrowed down to 9, as the remaining studies were deemed out of scope. (**Figure 1**).

#Insert Figure 1 here#

The obtained studies, published between 2012 and 2021, focused on interventions based on biofeedback or a combination of biofeedback with other interventions, specifically targeting workers or employees. **Table 2** provides an overview of the studies, including the year of publication, sample size, intervention type, and results. Results denote that despite the various techniques, sensors, and approaches to physiological data treatment, most studies followed a similar path and series of events. Each study collected physiological data, processed and analyzed it, and provided feedback through various means, such as physical screens, applications, experiences, or stimuli, to help participants engage with the intended intervention (**Figure 2**).

#Insert Table 2 here#

#Insert Figure 2 here#

To visually represent the main interventions identified in our selected studies, we created **Figure 3**, which demonstrates the relationships among the studies. Eight out of the nine selected studies reported positive results, being the highlighted study the only one that had an initial increase in stress levels. Breathing exercises/techniques combined with biofeedback were the predominant interventions, providing a simple method to reduce heart rate variability (HRV) and improve stress levels from both physiological and psychological perspectives.

#Insert Figure 3 here#

Biofeedback interventions with Breathing techniques/ training and RSA measures

Among the nine selected studies, a common approach was the use of breathing interventions and techniques to lower the breathing and heart rate (**Figure 3**). These techniques were delivered through different interventions, such as traditional biofeedback and smartphone-delivered biofeedback training.

Munafo et al. (2016) focused on synchronizing heart rate and abdominal respiration variations to maximize respiratory sinus arrhythmia (RSA), with participants receiving real-time feedback and guidance through visual displays (49). All the participants in this study reported a reduced heart rate (HR) at rest, lower levels of anxiety, better health perception, more energy, less fatigue and better social functioning after the intervention. Importantly, in comparison to the control group (same characteristic as the intervention group), those who underwent the biofeedback training showed a significant natural logarithm of RSA (lnRSA) increase and decreases in both systolic blood presure and logarithm of Skin conductance level (logSCL). Also, participants who underwent the biofeedback training experienced reduction of emotional interferences in work or other regular daily activities. Hsieh et al. (2020) explored various breathing techniques, including diaphragmatic breathing, paced breathing, pursed lips breathing, and RSA biofeedback (50). Brinkmann et al. (2020) utilized a mobile HRV training device equipped with an LED light and a blue breathing frequency indicator to guide participants in maximizing their HRV. The device provided real-time feedback and visual cues to synchronize breathing with the desired pattern (51). In this study we were able to see a significant impact in the clinical outcomes, with a small to medium effect size in the following outcomes: psychological and physiological parameters of stress: stress perception, coping, HRV parameters and cortisol, in both interventions proposed. Smith et al. (2020), used a wearable device to in order to prime the participants' awareness and prompt respiratory self-regulation (52). Chelidoni et al. (2020) developed a mobile application that delivered guided breathing exercises along with mindfulness body scans. These app incorporated visual and auditory cues to facilitate specific breathing rates, guiding participants towards optimal HRV levels (53). Gaggioli et al. (2014) integrated VR biofeedback into their intervention, immersing participants in virtual environments while simultaneously guiding them through deep breathing and muscle relaxation techniques (54). Sutarto et al. (2012) employed a light display that indicated the desired breathing frequency, helping participants synchronize their breath with the intended pattern. This study presents us with a high effect size regarding reducing negative emotional symptoms and significant improvements from the baseline follow-up assessment. Depression, anxiety and stress scores were significantly lower than in the control group. Also, resonant biofeedback produced a significant decrease in depression (58.3%), anxiety (37.5%), and stress (30.8%) scores in the biofeedback training group from pre- to post-intervention. It is important to mention the small sample size and the homogenous sample, being that these results should be carefully looked upon. Nonetheless, resonant breathing biofeedback training demonstrates promise for the new training approach for reducing negative emotional states.

Among the selected studies, only Orlando et al. (2021) reported unusual results, indicating a negative impact on physiological outcomes during the initial six weeks of the intervention (55).

Biofeedback interventions using Mobile-Applications

Besides focusing on breathing techniques, some mobile applications were reported to be used in two of the nine selected studies. One of them (53) used a commercial application, BioBase App, with guided breathing that has the ability to be modified according to the participants HR (physiological data collected through a wearable wrist band). This application also compiles mindfulness body scan and step-by-step instructions, including visual cues to facilitate relaxation and stress reduction. Participants were instructed to perform five minutes scans providing nonjudgmental acceptance of thoughts and feelings. Hsieh et al. (2020) implemented an app-directed self-managed protocol that included a guided meditation practice in the form of an MP4 file. Participants could follow along with the meditation exercises at their own pace, guided by the audio and visual instructions provided through the app (50). Smith et al. presented a commercial application, Spire Health, that allowed participants to visualize respiratory changes over time, observe real-time biofeedback, and receive real-time notifications of physiological stress.

Biofeedback interventions using Mindfulness/Meditation

Overall, the studies analyzed comprised more than one intervention technique, in order to provide better comparison between the techniques under study with other well-known stress reduction interventions. As so, three studies used Mindfulness interventions as a secondary/comparative intervention and one study used Meditation as a secondary path. Brinkmann et al. (2020), used traditional mindfulness-based stress reduction techniques with elements of self-compassion, acceptance, commitment and also Mindfulness-Based Cognitive Therapy. This formal guided meditation included mindfulness of breathing and mindfulness of thoughts, feelings and physiological sensations. Also, informal meditation practices were encouraged using brief pauses throughout the day to focus on present moment awareness without judging. Participants were also gifted a meditation CD with twelve guided meditations to support formal meditation at home. The second Mindfulness intervention in Chelidoni et al. (2020), involved using a mobile application that had mindfulness body scans with audio instructions, just like the first one. Participants were encouraged to focus and guide their attention to bodily and breathing sensations providing acceptance of thoughts and feelings in the present moment. The last study, Hsieh et al., defined the intervention as meditation, but kept the same principle as the studies before, with the exception of adding visual cues to the auditory stimulus (50). A video file was the guide to portrait meditation practice. The participants were tracked and checked in their progression by the researchers during the training via a in app cloud service.

Biofeedback interventions using VR and biosignal reactive training

Gaggioli et al. (2014) used VR experiences to manage stress (54). In the selected studies this is the only one that portraited VR experiences in the workplace. The protocol consisted in producing potentially stressful experiences, and afterwards, showing to the participants an immersive natural scenario used to learn specific relaxation techniques. The training sessions were composed of four stages: (1) homework checking, (2) exposure to a stressful VR environment, (3) relaxation techniques and (4) homework assignment. The relaxation techniques were induced though the immersion in a natural scenario selected by the participant. These experiences and scenarios are integrated with pre-recorded audio narratives with guidance to execute different deep breathing exercises and muscle relaxation techniques. Afterwards, the participants are instructed on how to use the smartphone and the body worn wireless sensor to do the contextualized homework. IR intervention significantly reduced anxiety, with a large effect size, being this the primary outcome of the study.

Biofeedback interventions using traditional Heart Rate monitoring and Cerebral Bloodflow

Amongst the selected studies, Kotozaki et al. (2014), shows a different approach into biofeedback and monitoring, including HR training, cerebral blood flow (CBF), saliva sampling and voxel-based morphometric measures (56). After the intervention, several clinical stress outputs, including the CES-D, PANAS-NA, and BSJQ-aptitude for job scores, as well as the BJSQ tension, BJSQ depression, and BJSQ stressors of working environment scores, significantly decreased when compared to the control group.

This study introduces a proprietary wearable device that utilizes near-infrared light at the isosbestic point of oxygenated and deoxygenated hemoglobin to measure concentrations of both oxygen and deoxyhemoglobin in brain tissues, along with heart rate. The biofeedback sessions were conducted using dedicated software on a personal computer.

Discussion

The results revealed a lack of studies focusing on biofeedback interventions specifically designed to enhance workers' psychological well-being and mental health. However, numerous studies have explored the use of biofeedback systems in different samples to improve mental health and well-being (57-64). Despite the limited focus on occupational settings, it is highly relevant to discuss our results in comparison to the most prevalent areas of biofeedback research, namely physical activity and rehabilitation. To provide a broader context, we created a PubMed citation library of the biofeedback literature using the same keywords as our query. Using VOSviewer 1.6.18, we visualized the obtained results (**Figure 4**). Here we can start out visual narrative checking despite the intentional inclusion of workplace-centric keywords in our research, the term "workplace" is not a prominent feature in the resultant diagram. The image clearly illustrates an important point: using biofeedback systems to improve mental health at work is an emergent and evolving field that remains relatively unexplored but holds significant potential to contribute to occupational health and safety.

#Insert Figure 4 here#

The selected studies in our review demonstrated consistent methods of presenting biofeedback information (24, 29, 65). Common approaches included the traditional display of HR, HRV, and RSA measures on a screen, as well as the use of visual or auditory cues to indicate the rate of relevant variables. Some studies went further, offering participants an immersive 3D experience that integrated physiological data with the intervention elements. This aligns with findings from other areas of biofeedback research, as most interventions tend to focus on the same methods and variables presented (66-70).

The results showed great potential in different interventions enabling great potential changes in clinical outcomes. All the selected studies had control groups, with the option to receive intervention later. However, the effects of the intervention were not measured in a medium to long-term and sample sizes were small. Having this in mind, the results should be carefully interpreted, and we shall look to the immediate effect of the interventions. For the purpose of this review, we will first focus on the studies that shown interesting and promising results.

As indicated in the results section, breathing techniques were the main intervention in eight out of the nine selected studies. These findings align with previous research on the implementation of breathing techniques for reducing physiological and psychological stress in adults (71-73). The main differences are the diverse methods used to present or perform biofeedback. We found five different methods included in our results: traditional biofeedback, mindfulness, app-directed interventions, immersive scenarios and in-depth physiological data presentation.

Regarding the comparison between breathing and mindfulness (51), we have seen no significant differences between the two techniques in terms of their impact on stress-related psychological and physiological parameters, such as stress perception, coping, HRV parameters, and cortisol levels. This information presents a great opportunity to widen the spectrum of available and effective interventions in the workplace to mitigate stress. However, app-directed interventions showed higher HRV at recovery compared to the mindfulness and control groups (53). It is important to note that this particular study included a stress induction protocol to induce "anger," identified to induce the highest physiological activation in heart rate among negative emotions (74). These results are supported from findings conducted with the same application but with a different sample of university students, reporting higher HRV. (75). We have also acknowledged interesting results regarding traditional biofeedback and app-directed interventions, being that app-directed showed significant improvements in depressive symptoms, resilience, and respiration rate (50). Concurrently the app-directed intervention also resulted in significant reductions in occupational stress. It is worth considering that traditional biofeedback can only be provided in a structured environment, such as the workplace, which itself can be a stressful environment. On the other hand, app-delivered biofeedback can be carried out during non-working hours, with very high flexibility and enrolling participants at a time that they may experience less stress, which could explain the observed results. Both groups exhibited slowed respiratory rates. Although effect sizes were not reported, significant p-values were obtained. In alignment, a study conducted in 2021 using a smartphone application for HRV measures found that individuals who used the app more frequently reported greater benefits (76). These results shed light into the direction that workplace interventions must prevail. Flexibility and ease of use can engage participant adherence and elevate interventions to the next level.

Concerning RSA measures, we observed a large effect size for RSA, skin conductance and respiratory exchange (49). In the same line, we encountered very insightful results in resonant breathing biofeedback with a high effect size in reducing negative emotional symptoms and significant improvements from baseline to follow-up assessment. Depression and anxiety were also significantly lower in the intervention group (77). These results hold hands with previous research in RSA biofeedback and resonant breathing biofeedback, with reported increase in HRV (78-80).

It is also worth noting that breathing techniques, mindfulness and app-directed interventions, are the easiest, most accessible, convenient and cost-effective interventions to implement in the workplace. In addition to the existing discussion, it is important to delve deeper into the mechanisms by which breathing techniques facilitate relaxation and stress reduction. Reducing the breathing frequency leads to autonomic changes that increase Heart

Rate Variability and Respiratory Sinus Arrhythmia, accompanied by modifications in Central Nervous System (CNS) activity (81). An available fMRI study highlights heightened activity in cortical (e.g., prefrontal, motor, and parietal cortices) and subcortical (e.g., pons, thalamus, sub-parabrachial nucleus, periaqueductal gray, and hypothalamus) structures (82). Regarding mindfulness, by leading individuals to focus on moment-by-moment occurrences rather than getting entangled in worry or rumination, mindfulness reduces amygdala activation, leading to decreased overall stress levels (83). Some studies have identified this sequential pattern of outcomes (84), which may clarify the stronger associations between stress and mindfulness observed in our cross-sectional analyses compared to our longitudinal analyses, where participants' mindfulness skills were newly acquired at the end of training. Mindfulness practices typically precede a reduction in perceived stress, suggesting that increased trait mindfulness may mediate the link between mindfulness training and stress reduction (85).

In respect to immersive scenarios provided by VR and real-time monitoring, our results shown significant reduction in anxiety, with a large effect size, as the primary outcome (54). Despite the interesting results and being able to integrate assessment and treatment within a hybrid environment that bridges the physical and virtual worlds, VR interventions can be costly, requiring expensive hardware, biosensors, and other resources. Yet, as the industry makes these technologies more affordable, the present research stablishes the foundation for further scrutiny in the field. A scoping review on virtual reality biofeedback in 2022 also highlighted the importance of these innovative interventions, which tend to have higher adherence rates and offer advantages such as increased motivation, improved user experience, higher engagement, and enhanced attentional focus (86).

Lastly, the study by Orlando et al. (2021) revealed an increase in stress levels during the first six weeks of the intervention, while the biofeedback procedure was conducted and supported by investigators. This negative effect was attributed to increased responsibilities and workload associated with daily biofeedback. Notably, this study employed self-regulation techniques and limited biofeedback access to desktop-based stations in the workplace, which posed logistical limitations. However, the remaining studies demonstrated positive results in physiological outcomes, showing significant differences between intervention and control groups. Several factors could explain this outcome, including the study design, participant characteristics, or the specific nature of the biofeedback intervention used. However, the additional effort required for participants in the study due to the structured nature of the workplace intervention seems to be the challenge. In this protocol, only two desktop-based sets were available, which required participants to allocate different times for the intervention. The small sample size also posed challenges.

Conclusion

This review explored the efficacy and applicability of biofeedback interventions in improving the psychological well-being and mental health of employees within occupational settings and highlights the ones that incorporate visual and/or auditory cues implanted in breathing techniques. These interventions are convenient, versatile, user-friendly, potentially cost-effective being able to reduce stress and improving physiological and psychological well-being among workers and employees with the minimum footprint possible. The diverse range of delivery methods and techniques provide flexibility in the deployment of biofeedback interventions tailored to individual needs and preferences, in the workplace.

By addressing mental health issues proactively, these interventions contribute significantly to the broader objectives of safety science. Firstly, enhancing mental well-being through biofeedback directly correlates with reduced workplace accidents, as a mentally healthy workforce is more alert, aware, and able to respond to potential hazards effectively.

Second, the improvement in employee mental health is inherently linked to increased productivity. Workers with better mental health are more engaged, motivated, and capable of performing tasks efficiently, driving organizational performance and growth. Ultimately, fostering a safer work environment through biofeedback interventions aligns with the strategic goals of occupational health initiatives. As mental health challenges in the workplace receive increasing recognition, integrating biofeedback into routine employee wellness programs becomes instrumental. These interventions serve as preventive measures, reducing the incidence of work-related stress, burnout, and psychosocial risks. Gracefully they not only ensure the individual well-being of employees but also contribute to a culture of safety, resilience, and sustainability within organizations.

Implications and Future challenges

This review may be of interest to researchers, mental health interventions' developers, and practitioners interested in the use of biofeedback in mental health management as it presents descriptions and analysis of nine examples of biofeedback-based interventions to improve workers' psychological well-being and mental health, including five different breathing techniques, application-based programs intervention, VR and CBF. The selected studies also provide a solid foundation into assessing the interventions feasibility, indicating not only standard questionnaires but also objective physiological measures/indicators.

We want to address some important limitations about the present review and selected studies: the small sample sizes limit the amount of data and generalization we can provide with the outcomes. As this is a growing and developing topic, in some months we can see a big growth in terms of the studies presented specifically in this field of occupational health and safety. We tried our best to include a very wide range of terms in the search query, despite that, other terms could come up with different and additional publications and last grey literature could also provide interesting reports, although being less desirable.

An important note regarding future challenges for this emergent risk in psychosocial factors is that the adherence is very low. We crave an effective jump from the laboratorial context to the real work environment. Recent approaches with higher engagement and user experience seem to bump adherence, for example VR and Augmented Reality, despite not being the ideal intervention for the work environment. Having this in mind there is a tremendous need for solutions that can provide better engagement rates, higher adherence, unobtrusive usage and solutions that can be human dependency free, working on their own and serving as tools, not as an added workload.

These digital systems are the first line of health monitoring in industries and enterprises. Biofeedback systems provide a window into understanding employees health states and psychophysiological states in order to improve occupational safety, security and prevent further costs, highly contributing for companies' sustainability.

The present review will lead future work in developing and implementing interventions to improve well-being and mental health in the workplaces, paving the way for a guided start. Furthermore, the use of biofeedback system can be elevated by being used also as an early detection tool, more than being only for intervention. The important collaboration with health care professionals and the industries will further strengthen the possibility for positive outbreaks in the workplace, and soon we will have better, safer, more sustainable and healthier workplaces. By implementing these interventions and fostering a culture that values mental well-being, we can transform the workplace into a space where employees thrive, creativity flourishes, and productivity soars. It's time to acknowledge the importance of mental health and take bold steps towards creating a healthier and happier workforce. After all, our collective success depends on the well-being of each individual.

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Conflicts of Interest

None declared

Abbreviations

BDI-II: Beck-Depression Inventory II
BJSQ: Brief Job Stress Questionnaire
CBT: Cognitive Behavioral Therapy
CES-D: Center for Epidemiologic Studies Depression Scale
CBF: Cerebral Blood Flow
CNS: Central Nervous System
ECG: Electrocardiography
EU: European Union
FCT: Fundação para a Ciência e a Tecnologia
FFA-14: Freiburg Mindfulness Inventory
FFMQ: Five Factor Mindfulness Questionnaire
HF: High Frequency (in HRV metrics)
HR: Heart Rate
HRV: Heart Rate Variability
JMIR: Journal of Medical Internet Research
LF: Low Frequency (in HRV metrics)
MASQ: Mood & Anxiety Symptoms Questionnaire
MBI: Mindfulness-Based Interventions
MBSR: Mindfulness-Based Stress Reduction
OECD: Organization for Economic Co-operation and Development
OSI-2: Occupational Stress Indicator-2
PANAS: Positive and Negative Affect Schedule
PEDro: Physiotherapy Evidence Database
PSS: Perceived Stress Scale
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: Randomized Controlled Trial
RMSSD: Root Mean Square of Successive Differences
RSA: Respiratory Sinus Arrhythmia
SCL: Skin Conductance Level
SDNN: Standard Deviation of NN intervals
SF-36: Short Form Health Survey
STAI-Y: State-Trait Anxiety Inventory Form Y
SWLS: Satisfaction with Life Scale
VAS: Visual Analog Scale
VBM: Voxel-Based Morphometry
VR: Virtual Reality
VOSviewer: Visualization of Similarities mapping software

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Table 1. Keywords used for the search

Keyword family	Specific search terms
Mental health and job performance AND	“fatigue” OR “lassitude” OR “mental health” OR “mental disorders” OR “stress” OR “mood disorders” OR “behavioral symptoms” OR “anxiety” OR “burnout” OR “absenteeism” OR “Job performance” OR “Performance at Work” OR “productivity” OR “efficiency” OR “Occupational Stress” OR “Job satisfaction” OR “Quality of working life”
Biofeedback AND	“biofeedback” OR “bio-feedback” OR “feedback” OR “wearable” OR “wearable electronic devices” OR “monitoring, physiological” OR “clinical alarms” OR “outcome measures” OR “real time” OR “self-monitoring”

Workplace	“job” OR “job site” OR “workplace” OR “work place” OR “worker” OR “employee” OR “occupation” OR “operators” or “Occupational”

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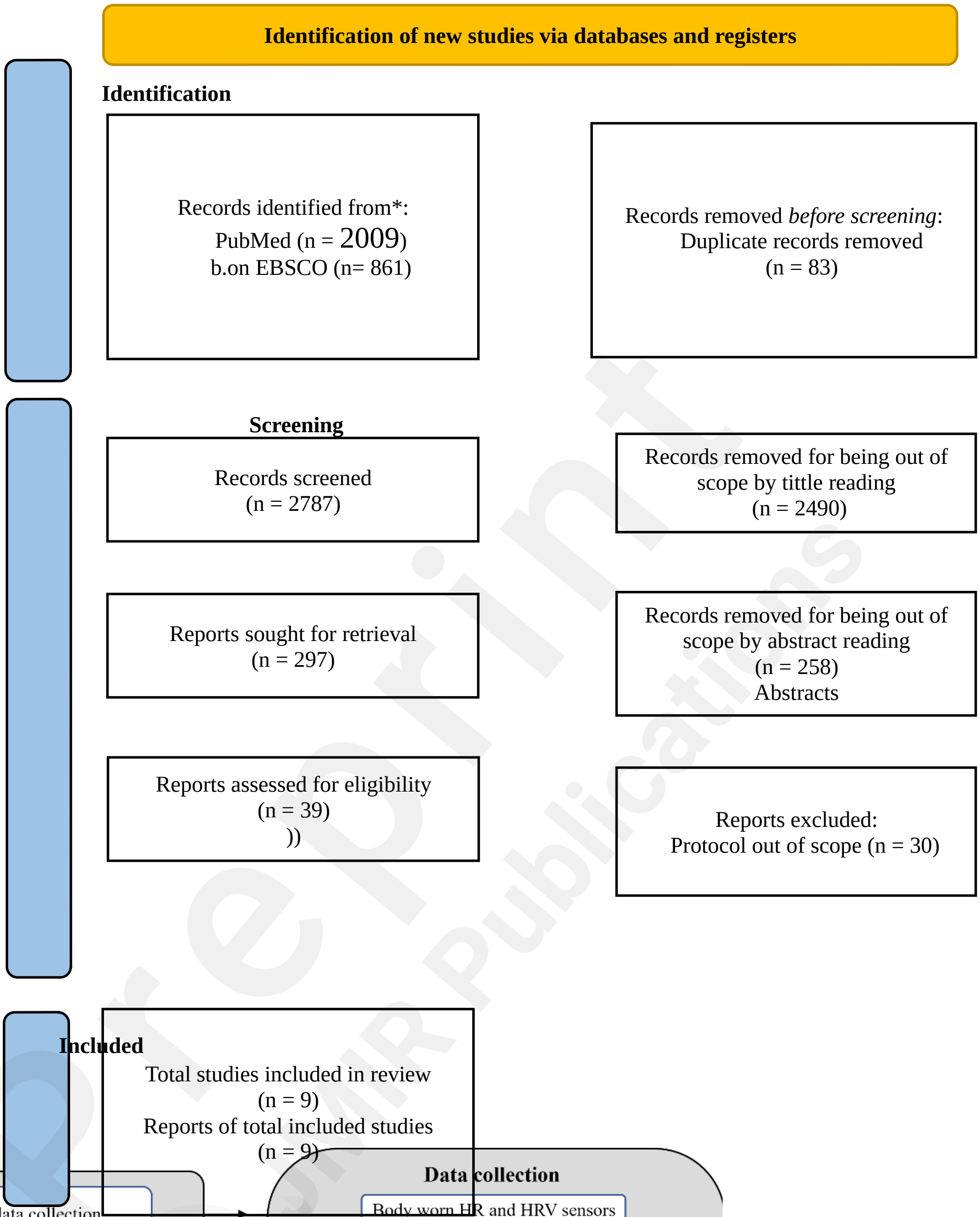

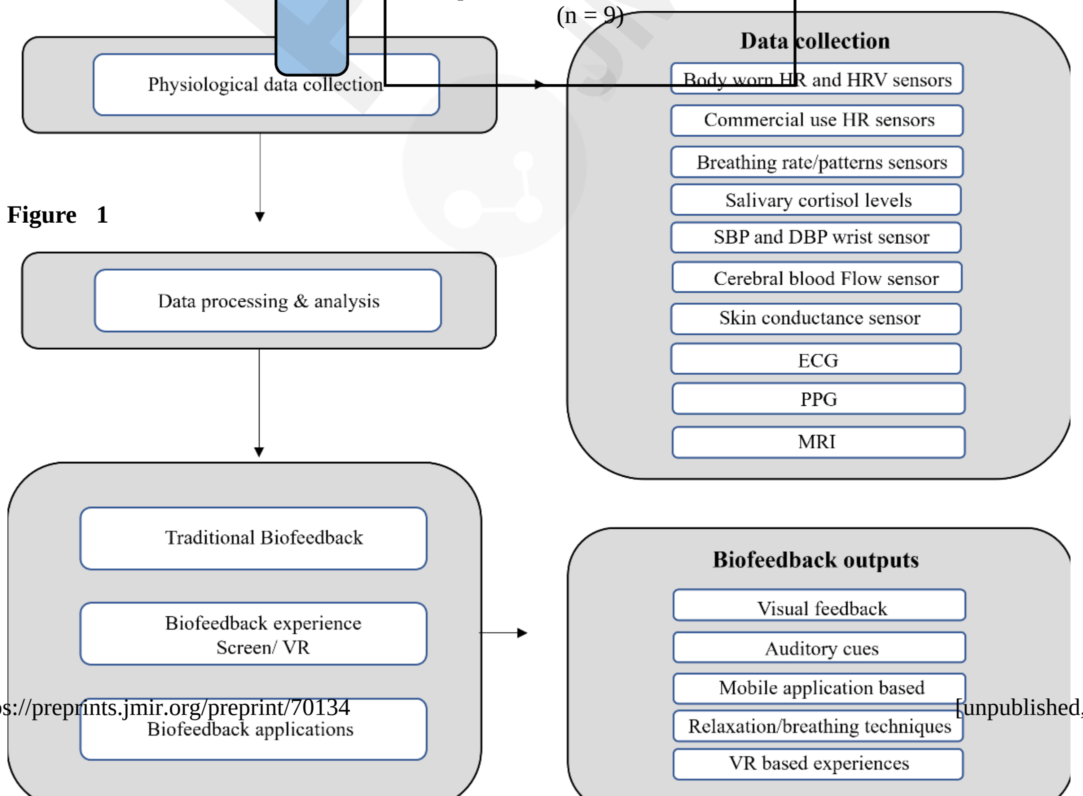

Figure 1 Flowchart of the systematic review following the PRISMA statement

Figure 2. Process across all the selected studies from data collection to intervention models

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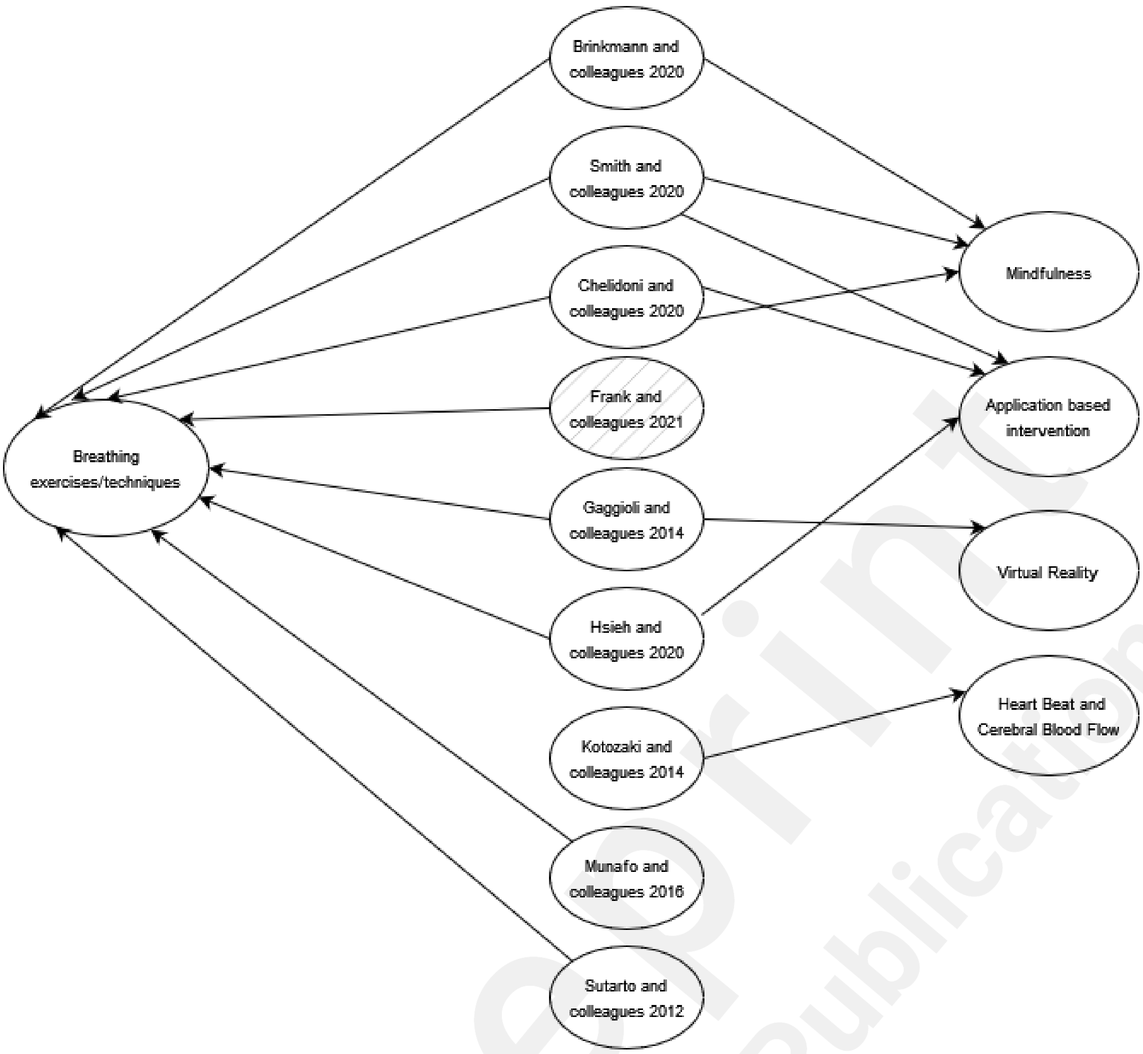

Figure 3. Intervention diagram from the final selected studies.

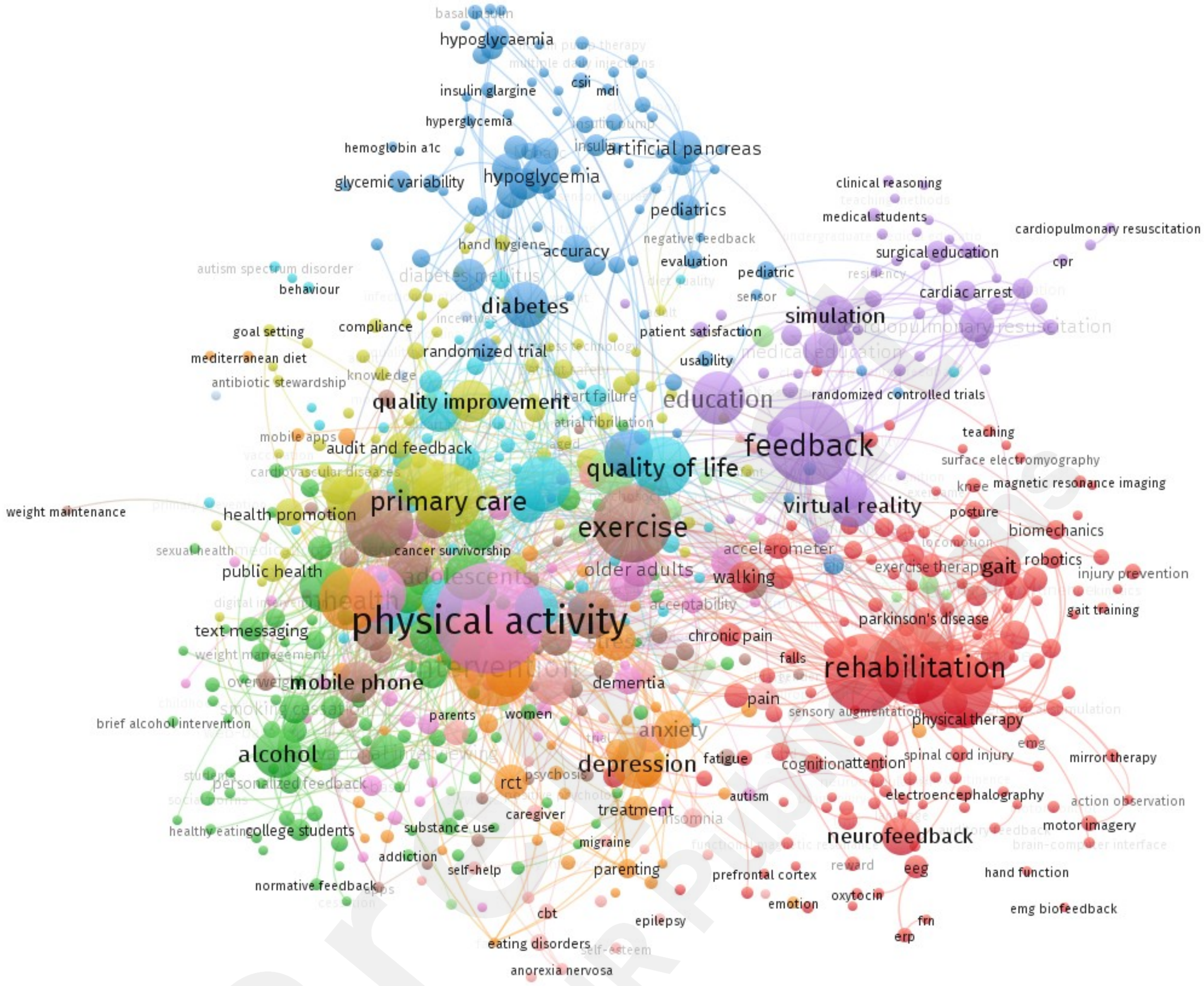

Figure 4. Visualization of the Biofeedback publications in the last 10 years

Table 2. *Selected studies (n=9)*

Study	Sample	Intervention	Measures	Results	Follow up
Sutarto et al. (2012)	36 workers from a manufacturing company producing electronic parts located in Malaysia (Biofeedback n=19, Control n= 17)	Five sessions of HRV biofeedback training, one session per week. The control group was physically monitored with no feedback instructions with the same cadency.	**Questionnaires:** Trier Inventory for Chronic Stress; Mini-DIPS; Stress perception; Coping. ________________________ **Physiological parameters:** HRV parameters: RMSSD, SDNN; Cortisol.	High effect size regarding reducing negative emotional symptoms and significant improvements from the baseline follow-up assessment	**Time 1:** First Session **Time 2:** 1 week after the final training
Kotozaki et al. (2014)	30 Right-handed workers, native from Japan (Biofeedback n=15, Control n=15)	5 minutes of biofeedback training (joint task of cerebral blood flow and heart rate) every day for 4 weeks.	**Questionnaires:** Center for Epidemiologic Studies Depression Scale; General Health Questionnaire 30; Positive and Negative Affect Schedule (PANAS); Brief Job Stress Questionnaire (BJSQ). _________________________ **Physiological parameters:** Cortisol; MRI; Voxel-based morphometry (VBM).	Significant decrease in clinical stress outputs after the intervention (CES-D, PANAS-NA*), as well as a decrease in work stressors score.	**Time 1:** First Session **Time 2:** 4 weeks after the start of the intervention.
Gaggioli et al. (2014)	61 high school teachers recruited in Milan. 60 pediatric nurses from Messina, Italy.	(1) Experimental Group (EG): n=40; B1=20, B2=20, which received a 5-week (2 sessions per week) treatment based on the Interreality paradigm. (2) Control Group (CG): n=42; B1=22, B2=20. 5-week (2 sessions per week) traditional stress management training based	**Questionnaires:** Visual Analogue Scale for Anxiety (VAS-A); State-Trait Anxiety Inventory Form Y-1 (STAI-Y1); Coping Orientation to the Problems Experienced (COPE) Inventory; The Perceived Stress Scale (PSS); Psychological Stress Measure (PSM); Satisfaction with Life Scale (SWLS); Visual Analogue Scale for Anxiety (VAS-A). _________________________ **Physiological parameters:** Heart rate and HRV.	"Interreality" intervention significantly reduced anxiety, with a large effect size, being this the primary outcome of the study. The stress outcomes also reduced when compared to the control group.	**Time 1:** Session 1 **Time 2:** Session 10

		on cognitive behavioral therapy (CBT); and (3) the Wait-List group (WL): n=39, B1=19, B2=20, which was reassessed and compared with the two other groups 5 weeks after the initial evaluation.			
Munafo et al. (2016)	31 managers from a private banking from the Northeast of Italy (Biofeedback n = 16, Control n = 15)	Each week, there were five 45-minute sessions. Participants were given biofeedback instructions, and the advice was to synchronize heart rate variations and abdominal breathing until the two signals covariated.	**Questionnaires:** Sociodemographic variables (age and education, health behavior data, weight, height, physical activity, sleep time, family history of hypertension and cardiovascular disease, a semi-structured interview) State-Trait Anxiety Inventory STAI-Y - STAI-Y2; Short Form Health Survey (SF-36). _________________________ **Physiological parameters:** Photoplethysmography. Respiration rate. SBP and DPB; Skin conductance level (SCL).	Medium effect size in SBP# and large effect size in respiratory sinus arrhythmia. All the participants reported a reduced heartrate at rest, lower levels of anxiety, better health perception, more energy, less fatigue and better social functioning after the intervention.	**Time 1:** 1 week before the training **Time 2:** 2 weeks after the end of the training
Hsieh et al. (2020)	135 psychiatry ward nurses in Taiwan (Biofeedback n = 49, Smartphone-based intervention n = 47, Control n = 39)	Every participant went through a two-hour resilience-building course. The biofeedback training protocol included self-guided progressive muscle relaxation, diaphragmatic breathing, and other types of breathing, all of which were performed in 60-minute sessions weekly	**Questionnaires:** Demographic variables; Rehabilitation Strength Chart; Simplified Health Scale; Centre for Epidemiologic Studies Depression scale (CES-D); Occupational Stress Indicator-2 (OSI-2); Resilience Scale (RS). _________________________ **Physiological parameters:** HRV: SDNN, LF, HF; Respiration Rate; RSA.	Significant improvements in depressive symptoms, resilience, and respiration rate. The Smart phone delivered shown significant reductions in occupational stress.	**Time 1:** week 0 **Time 2:** week 6

		for six weeks. (1) diaphragmatic breathing, (2) paced breathing, (3) pursed lips breathing and also (4) RSA** biofeedback.			
Brinkmann et al. (2020)	69 healthy workers from Germany (Biofeedback n = 23, mindfulness-based interventions n = 19, control n = 27)	Participants were told to practice for half an hour every day and to fill out a daily self-report. Q&A sessions were held twice (After weeks 1 and 3) The trainings were guided by experienced trainers in either HRV-Bfb or MBI.	**Questionnaires:** SVF-120:stress-coping questionnaire; Positive (POS) and Negative (NEG) coping strategies; Beck-depression inventory (BDI-II); Hamburg Modules for the Assessment of Psychosocial Health in Clinical Practice (HEALTH-49); Freiburg Mindfulness Inventory (FFA-14); Self-compassion Scale (SCS). __________________________ **Physiological parameters:** ECG; RSA; HRV; Cortisol.	No significant differences between biofeedback and mindfulness-based interventions were found. Both interventions had a significant impact in the clinical outcomes, with a small to medium effect size in the primary outcomes (psychological and physiological parameters of stress: stress perception, coping, HRV parameters and cortisol).	**Time 1:** Baseline (1st Session) **Time 2:** After the program (6 weeks) **Time 3:** 6 weeks after the program ended (12 weeks)
Chelidoni et al. (2020)	75 full-time working adults from England (BioBase breathing n=25, Mindfulness body scan n=25, Control n=25)	Subjects were monitored for a baseline period, followed by a stressor period, which included 2 cognitive tasks and 2 emotion-eliciting film clips. They were then randomly assigned to: BioBase app, mindfulness body scan, or	**Questionnaires:** Continuous Performance Task; Neuropsychological performance-based task; Go/No-Go; Emotional stress: 2 emotion-eliciting film clips; Five Factor Mindfulness Questionnaire (FFMQ); Samn-Perelli Fatigue Checklist; Stanford Sleepiness Scale; Visual Analog Scale (VAS); __________________________ **Physiological parameters:** HRV; Breathing rate.	HRV was higher at recovery for participants who enrolled in the APP directed intervention against the mindfulness and control group. Significant difference between the before and after in the groups with a small effect size.	**Time 1:** baseline in sessions and and during cognitive and emotional stress induction tasks. Data collection took place always in sessions, without point a pre and post

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		control.			evaluation.
Smith et al. (2020)	169 office workers from seven US cities (Biofeedback n= 67, Control n= 102)	Mindfulness-based stress reduction (MBSR) programs and four wearable-based treatment components: 1) wearing of the device itself, 2) tracking and visualization of past physiological states, 3) visual real-time biofeedback, and 4) real-time notifications on significant and sustained changes of the user's respiratory patterns.	**Questionnaires:** Perceived Stress Scale (PSS); Mood & Anxiety Symptoms Questionnaire (MASQ); CDC Healthy Days – Days Anxious; Stress quantification (Likert); CDC Healthy Days – Days Sad or in Poor Mental Health; Positive and Negative Affect Schedule (PANAS); Engagement and Fidelity measures.	After the 4-week intervention period, the treatment group reported experiencing 15.8% fewer negative instances of stress, 13.0% fewer distressing symptoms, and 28.2% fewer days feeling anxious or stressed compared to control. There were also find marginal evidence that the treatment group reported fewer negative emotions, but do not find robust evidence that the intervention increased broad measures of well-being.	**Time 1:** Pre-study survey (1 week) **Time 2:** Email to download fully featured app and being 4-week intervention (week 2) **Time 3:** After the 4-week intervention they answers post-study survey.
Orlando et al. (2021)	18 health workers from two family medicine clinics from California	(Biofeedback n= 9, Control n=9) 1-h training session to learn quick-coherenc e self-regulation techniques and practiced using the emWave Pro biofeedback device in the workplace. The biofeedback group were asked to perform five	**Questionnaires:** Demographic variables; Perceived Stress Scale (PSS); Minnesota Satisfaction Questionnaire— Short Form (MSQ-SF); Biofeedback minutes. __________________________ **Physiological parameters:** Cardiac Coherence Achievement Score; Respiratory Data.	The treatment group received one biofeedback session per week for 6 minutes, while the control group had two sessions for 11 minutes. Perceived stress initially increased in both groups, particularly in the treatment group, but	**Time 1:** Baseline **Time 2:** 6 weeks of treatment **Time 3:** 12 weeks of treatment

	minutes of daily self-regulation with optional biofeedback over 12 weeks, the first 6 of which included weekly peer support		subsequently decreased without statistical significance.

HRV: Heart Rate Variability; RMSSD: root mean square of successive differences between normal heartbeats; SDNN: standard deviation of NN intervals
SBP: Systolic blood pressure; DPB: Diastolic blood pressure; LF: Low Frequency & HF: High Frequency (related to HRV Measures); RSA: Respiratory sinus arrhythmia, heart rate variability in synchrony with respiration; HRV-Bfb: heart rate variability-biofeedback; MBI: mindfulness-based interventions; ECG: Electrocardiogram.
CES-D, PANAS-NA: Depression and Affect Scales, respectively.

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Supplementary Files

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CONSORT (or other) checklists

PEDro Results.
URL: http://asset.jmir.pub/assets/b10f838c97ab7384137b6496e7c1e883.pdf

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