

The Advances of Immersive Virtual Reality Interventions for the Enhancement of Stress Management and Relaxation among Healthy Adults: A Systematic Review

Maria Velana ^{1,*} , Sabrina Sobieraj ¹, Jan Digutsch ²  and Gerhard Rinkenauer ¹

¹ Department of Ergonomics, Leibniz Research Centre for Working Environment and Human Factors at the Technical University Dortmund, 44139 Dortmund, Germany; sobieraj@ifado.de (S.S.); rinkenaus@ifado.de (G.R.)

² Department of Psychology and Neurosciences, Leibniz Research Centre for Working Environment and Human Factors at the Technical University Dortmund, 44139 Dortmund, Germany; digutsch@ifado.de

* Correspondence: velana@ifado.de; Tel.: +49-231-1084-263

Abstract: The rapid changes in human contacts due to the COVID-19 crisis have not only posed a huge burden on the population's health but may have also increased the demand for evidence-based psychological programs delivered through digital technology. A systematic review, following the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" guidelines, was therefore conducted to explore the advances in stress management interventions utilizing VR and suggest up-to-date directions for future practice. The relevant literature was screened and the search resulted in 22,312 records, of which 16 studies were considered for analysis. The Methodological Index for Non-Randomized Studies (MINORS) was also employed to assess the quality of the included studies. The results suggest that VR-based interventions can facilitate positive changes in subjective stress levels and stress-related biomarkers. However, special attention should be paid to the development of rigorous VR protocols that embrace natural elements and concepts deriving from traditional treatment approaches, such as cognitive behavioral therapy techniques. Overall, this review aims to empower future researchers to grasp the opportunity that the COVID-19 pandemic generated and utilize digital technologies for strengthening individuals' mental health. Future projects need to conduct large-scale VR studies to evaluate their effectiveness compared to other mental health interventions.

Keywords: immersive virtual reality; health; stress management; relaxation; interventions; cognitive behavioral therapy; healthy adults; advances; systematic review



Citation: Velana, M.; Sobieraj, S.; Digutsch, J.; Rinkenauer, G. The Advances of Immersive Virtual Reality Interventions for the Enhancement of Stress Management and Relaxation among Healthy Adults: A Systematic Review. *Appl. Sci.* **2022**, *12*, 7309. <https://doi.org/10.3390/app12147309>

Academic Editor: Dimitris Mourtzis

Received: 20 June 2022

Accepted: 19 July 2022

Published: 20 July 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Virtual reality (VR) technologies such as Oculus Rift or Sony PlayStation, have attracted the attention of many users over the last couple of years [1]. By 2023, VR market volume is expected to reach 98.4 million sales with a worldwide population penetration of 2% [2]. The concept of VR was first formulated by Sutherland [3] and was initiated in the field of computer sciences. Nowadays, it has also become a tool for psychologists, neuroscientists, and biologists in scientific research. Cipresso et al. [1] divided VR technologies into three eras. First, the pioneering era (about 1965–1990) in which VR was used for children and medicine, routine use and behavioral assessment, special effects, systems perspectives, and tutorials. In the development era (about 1990–2005), VR was used in clinical systems, telemedicine, human spatial navigation, and the first therapeutic interventions. The current era, the authors call it the *clinical VR* era, has a strong emphasis on rehabilitation, neurosurgery, and therapy.

VR is able to create an immersive experience, usually mediated through a headset, in which the real world cannot be seen. VR users can rotate and move as they would in the real world. The virtual environment also responds to the user's actions. The concepts of

immersion and presence are of fundamental relevance to the definition of VR characteristics. Whereas immersion is a property of the virtual environment, presence can be seen as a property of the user [4]. Immersion is achieved when individuals can interact with a digital world that is as real and similar to the real world as possible. Thus, it can be defined as the extent to which virtual environments are able to provide human participants with a comprehensive, encompassing, ambient, and vivid illusion of the reality (e.g., [4]). The more immersive a virtual environment, the stronger an individual's attention is diverted from the real world [5]. Presence is commonly described as the feeling of being present in a virtual environment rather than in the physical place, where the person is [6–9]. The component of presence is considered to be a profound achievement of VR.

In the clinical context, immersive VR technologies are used for effective pain management in patients. Distraction techniques have been used for more than two decades, for example, to distract from pain in the context of medical treatment for children [10]. The assumption is that focusing attention on harmful stimuli increases pain perception and diverting attention away from these stimuli attenuates pain perception [5]. In this regard, immersive VR technologies can be superior to traditional distraction techniques (e.g., watching movies or listening to music). It is hypothesized that the stronger the feeling of presence in the virtual world is, or the more immersive the stimulation is, the more effectively pain perception can be modulated. This phenomenon is also known as sensory shielding [11]. For instance, a study of patients undergoing dental procedures showed that VR reduced anxiety, discomfort, and the time required for each procedure [12]. In addition, VR distraction has been shown to decrease pain effectively during bandage changes in burn victims [13]. Recent studies with regard to the analgesic effects of VR during surgical procedures showed that pain reduction was associated with a decrease in heart rate, respiratory rate, oral secretions, and blood pressure [14,15].

VR technologies may be seen, however, as a tool that is not only utilized in clinical settings, but also as a means with a broader spectrum of applications. The growing development of such technologies can lead to the dissemination of novel systems that may be adopted from preventive medicine during times of crisis, such as the COVID-19 pandemic, and the era after it. In line with this, the current pandemic may be viewed as an opportunity to clearly embed VR systems in daily routines in order to improve the population's mental health irrespective of the surrounding conditions. Indeed, one of society's unprecedented challenges is stress and the associated serious health consequences for the years to come [16]. Indeed, roughly 7 in 10 adults report that they have experienced increased stress during the last years. According to a meta-review of meta-analyses, the overall estimated prevalence of psychophysiological stress is roughly 32% in the population around the globe [17]. Although stress has primarily a psychological origin, the exposure to a stressor releases several complex physiological processes in the human body [18]. In particular, stress triggers the autonomic nervous system (ANS): the sympathetic nervous system is activated, while the parasympathetic nervous system is suppressed. In turn, this causes the secretion of stress hormones (e.g., cortisol and adrenalin) into the bloodstream in an effort to reestablish body balance [19]. These hormones can intensify a person's ability to concentrate and react, and at the same time, can lead to increased blood pressure, increased muscle contraction, and a change in cardiac activity [20]. This acute stress response describes the well-known "fight-or-flight" reaction. After the organism has dealt with the stressor, the production of stress hormones is inhibited and the human body returns to normal through homeostasis, where a balance between the parasympathetic and sympathetic systems is established [18]. In the long term, repeated exposure to situations associated with high levels of psychophysiological arousal can affect the body's ability to recover after stress and result in serious health consequences, including, for example, impairment of the immune system, delay of the healing processes, anxiety, depression, and sleep disorders [18,20]. As mentioned before, stress is a complex reaction to internal or external threatening stimuli and can be a confounding factor when it is examined together with other psychological disorders. In psychiatry, stress is particularly seen as

a transdiagnostic factor that may be associated with the onset, course, and recurrence of mood and psychotic disorders [21,22]. This fact may highlight the need to develop specialized therapies for people with serious mental health problems considering their particular demands for mental healthcare. For this reason, the authors focused their search only on healthy adults.

How individuals perceive stressors and cope with them can vary largely depending on their current available resources to confront these demands [23]. Traditional preventive programs focus on empowering people to alleviate the stressful impact of such situations, either by changing characteristics of the situation per se or by regulating habitual patterns of intrusive thoughts and negative emotions. During the last few decades, evidence has indicated that interventions with cognitive behavioral components can effectively reduce stress among adults [24,25]. Further research on job-related stress highlights the positive effects of interventions on stress management and healthcare providers' mental health, involving relaxation techniques, mindfulness, and meditation [26,27]. Additionally, another study that employed a randomized controlled trial research design, explored the impact of a brief online mindfulness-based program on health outcomes in students [28]. Cavanagh et al. [28] revealed that short self-guided interventions decreased perceived stress and depression/anxiety symptoms within the study population; also, this study provided important evidence in support of the feasibility of online mindfulness-based programs. In line with these results, technology-assisted interventions may have the potential to reduce stress and offer several benefits that may overcome some of the restrictions of face-to-face approaches, such as high protection of anonymity, high accessibility, and reduced implementation costs [29].

As described above, one of the most effective ways to reduce individuals' stress is through techniques that target the modulation of emotional and cognitive reactivity. In this context, VR can be a very effective tool for learning and applying such techniques. VR scenarios usually present naturalistic environments (beaches, oceans, mountains, etc.) that can reduce anxiety and stress [30] and improve mental health in general. In this context, it has been demonstrated that natural scenarios accompanied by appropriate natural sounds can enhance stress-reducing effects [31]. Moreover, there is an emerging body of studies that explores the implementation of self-help VR tools to tackle the negative consequences of the COVID-19 pandemic among individuals. For example, Riva et al. [32] proposed the "Secret Garden" protocol, a VR video, which stimulates a natural environment and offers an experience of immersion and presence. The user has the opportunity to perform daily exercises related to personal identity and interpersonal relationships along with a partner so as to decrease the psychological burden and the potential emotional side effects of isolation during the coronavirus. In more detail, they applied the VR treatment protocol to Italian-speaking citizens utilizing a before and after study design [33]. The implementation phase lasted one week, including a two-week follow-up after the intervention. The findings indicated that a VR-assisted program can produce a positive effect on participants' health. COVID Feel Good is also available in 12 different languages to help people to deal with stress associated with the COVID-19 pandemic. Furthermore, another research work examined the effectiveness of VR simulation on stress responses among COVID-19 frontline healthcare professionals [34]. In particular, the Cinematic-VR environment depicted an attractive, nature scene aiming to encourage states of relaxation and peace during professionals' work breaks. The participants could experience subtle details, such as forest sounds with birds singing and wind blowing, throughout the three-minute VR session. The study results showed that this Tranquil Cine-VR simulation did effectively reduce self-reported stress among frontline healthcare workers. However, they highlighted the importance of comparing Cine-VR application with a control group and assessing the measured parameters over time. Additional possible VR approaches to stress management can include the presentation of various theory-based contents inspired by traditional therapy protocols, such as progressive muscle relaxation, autogenic training, and meditation [35,36]. These concepts may be extensively incorporated into daily life so as

to enhance healthy individuals' resources and lower the risk of serious health issues. Before the broad implementation of VR programs, it is, nevertheless, essential that the research community delve into the advances in the field of VR and stress over the last decade. Hence, this literature review intends to contribute to primary prevention by introducing the most recent developments regarding stress management in immersive VR, and motivate scientists to adopt modern tools for health promotion.

It seems that the outbreak of the current pandemic has rapidly changed the world in a unique way and highlighted even more the value of e-mental health implementations. Indeed, the only option for the provision of effective mental healthcare during the period of strict social contacts might be technological solutions [37]. The integration of VR as a tool of stress management into mental healthcare may offer a radical transformation of the traditional preventive programs [38], allowing people, in parallel, to have access to high-quality and cost-effective interventions irrespective of the surrounding conditions. The purpose of the present literature review is, therefore, to explore the advances in stress management interventions utilizing VR. In particular, this piece of work aims to better understand the effectiveness of stress management interventions to reduce stress and, consequently, enhance relaxation by utilizing virtual reality applications in healthy adults by embracing articles published after 2011. Moreover, special attention is paid to the techniques that were implemented to achieve the desired results, and to what extent selected studies examined theory-driven approaches. Furthermore, focus is given to the main features of VR (i.e., immersion and presence). Lastly, this review targets at providing future research and practice with fruitful evidence-based directions adapted to the current needs of people.

2. Methods

2.1. Search Strategies

VR technologies that have emerged within the clinical research field and mental health in recent years, enable effective interventions related to pain management and modulation of symptoms deriving either from different mental disorders, such as depression, or stressful events. In fact, 2016 was announced by the research community in the area of computer technology "the 1st year of VR" due to the increased attention that VR has drawn recently [39]. Thus, the authors decided to focus on the advances of the last decade so that they would deliver thorough insight into the benefits of VR interventions and at the same time, suggest up-to-date directions for future studies that would align with the present global challenges. The first step to investigate the current state of science regarding VR applications for stress management and relaxation among healthy adults involved the identification of studies published between January 2011 and November 2021. For this purpose, the following electronic sources were selected: EBSCOhost, Dortmund University Library, PubMed, Medline, Google Scholar and IEEE Xplore, and reference lists from relevant articles. Specific search strategies were applied for each database to detect relevant VR interventions for this literature review. The current literature search was performed utilizing the next key terms: stress (reduction), (immersive) virtual reality, relaxation, biofeedback, and neurofeedback, in various combinations. In particular, the following keyword combinations were applied: stress reduction AND immersive virtual reality, stress reduction AND virtual reality, stress AND relaxation AND immersive virtual reality AND biofeedback, stress AND relaxation AND virtual reality AND biofeedback, stress AND relaxation AND immersive virtual reality AND neurofeedback, stress AND relaxation AND virtual reality AND neurofeedback. Special attention was given to the differences among the databases in regard to vocabulary and syntax rules. The search was performed in November 2021.

The review protocol contained two main steps: the first step involved reviewing databases, while the second step consisted of identifying and screening all relevant studies according to inclusion and exclusion criteria. In order to ensure consistency and rigor, the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" guidelines were utilized [40].

2.2. Selection Criteria

As this review concerns healthy adults, only empirical research articles that included healthy participants (age 18 and over), aiming at stress reduction with or without (neuro)bio feedback, were included in the final sample. Furthermore, two stress management interventions should have been compared to each other; one of them should have included VR technology. Alternatively, a VR intervention should have been compared to a control or placebo group in a prospective way. For instance, randomized controlled studies with or without random assignment, studies with experimental designs, and pre–posttest design studies with control group and/or placebo cohort were considered for further evaluation. Furthermore, studies with within-subjects design were accepted for assessment. Studies were also considered for further analysis if the components of the stress management intervention, such as methods, frequency, and duration of the intervention, were clearly described. Primary outcome was defined as a change in individual stress level or stress symptoms, which were measured by objective or subjective instruments with evidence of validity. In cases where stress-related parameters were not available, changes in relaxation or in affective state were examined. Secondary outcomes could be, but were not limited to: burnout, depression, anxiety, mindfulness, quality of life, etc. Only articles published in English were included in the present review.

The exclusion criteria were: (a) interventions that focused not only on healthy adults but also on other populations (i.e., clinical populations and children) or studies that included solely patients or children, (b) studies that employed a before and after design with one group, (c) pure qualitative studies, case reports, comments, theses, editorials, abstracts, meta-analyses, and reviews, (d) studies aiming at organization level changes, and (e) articles published in conference proceedings and/or book chapters.

2.3. Quality Appraisal

The Methodological Index for Non-Randomized studies (MINORS) was utilized for the quality assessment of the included studies independently by the reviewers [41,42]. The checklist contains 12 items: the first eight items refer to non-comparative studies, whereas all 12 items are related to comparative studies. Each component is scored 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate) based on the adequacy of reporting and methodology. Hence, the total score would be 24 points for comparative studies and 16 points for non-comparative studies. In this review, all included papers referred to comparative studies and, consequently, the ideal MINORS score was considered 24 points. In order to provide the reader with in-depth insight of the results, the overall quality of the study sample was judged by the reviewers on a spectrum of excellent, good, fair, and poor as adopted by Boutris et al. [42]. Disagreements were discussed to reach consensus on quality assessment.

2.4. Data Extraction

The data were extracted and inserted into a pre-defined data extraction worksheet in Excel. The particular headings of the review table were selected according to the main aims of the study and previous research work in the area of mental health prevention, stress, and technology [38,43–45]. Table 1 summarizes all relevant characteristics of identified studies. In particular, the headings include: (1) the study characteristics, which refer to authors' details, the place of study, and the sample size, and (2) the intervention characteristics, which contain important information regarding the experimental design that was applied by each research group, and the stressor that was used to elicit psychophysiological arousal. Furthermore, the column VR task presents the intervention that was employed for reducing stress and improving participants' relaxation state. Lastly, the heading of measurement tools describes how the main outcomes were quantified, and the findings summarize the main results of each study. This process was checked by the review authors. Section 3.2 describes in detail the content of the table and the extracted data.

Table 1. Summary of articles included in the current literature review.

Author and Place	Sample Size	Design	Stressor	VR Task	Subjective Tools	Objective Tools	Main Findings
1. Anderson et al. [46], USA	Total (N = 18): Dream Beach, Ireland, indoor control	Within-subjects experiment	Arithmetic test	Videos of landscapes	PANAS MRJPQ VVR	SCR HRV: LF, HF, LF/HF	↓SCR in Dream Beach ($p = 0.001$) ↑HF ($p = 0.05$) and ↓LF/HF ($p = 0.02$) in Dream Beach ↑VR experience ($p < 0.001$) ↑Benefit and value ($p < 0.05$)
2. Annerstedt et al. [31], Sweden	Total (N = 30): VR with sound ($n = 10$), VR no sound ($n = 10$), control ($n = 10$)	Between-subjects experiment	Virtual TSST	Videos of forest landscapes	Modified STAI-S Single item on stress	Cortisol TWA HRV: HF, HF ln, HF nu, LF, LF ln, LF nu, LF/HF TOT, TOT ln HR	↓Cortisol in VR cond. ($p < 0.001$, $\epsilon = 0.71$) ↑HF in VR sound and in control ($p = 0.008$, $\epsilon = 0.89$)
3. Blum et al. [47], Germany	Total (N = 60): Standard HRV-BF ($n = 29$); VR HRV-BF ($n = 31$)	Double-blind, between-subjects experiment	Modified Stroop test	Video of beach scenery at sunset	STAI-S CIQ SMS VAS for relaxation self-efficacy and BF experience	HR HRV: Cardiac coherence, RMSSD Stroop test	↓Anxiety in VR-BF ($p = 0.02$, $\eta_p^2 = 0.08$) ↑Self-efficacy in VR-BF ($p = 0.03$, $\eta_p^2 = 0.07$) ↑Mind ($p = 0.002$, $\eta_p^2 = 0.15$) and body mindfulness ($p = 0.002$, $\eta_p^2 = 0.14$) in VF-BF ↓Scores in task-related ($p = 0.02$, $\eta_p^2 = 0.08$) and -irrelevant subscales ($p = 0.01$, $\eta_p^2 = 0.10$) in VR-BF ↑Stroop test performance in VR-BF ($p = 0.005$, $\eta_p^2 = 0.12$) ↑Experience with VR-BF ($p = 0.01$, $\eta_p^2 = 0.10$)
4. Gao et al. [48], China	Total (N = 120): GrS ($n = 20$), BS ($n = 20$), OG ($n = 20$), POG ($n = 20$), PCG ($n = 20$), CG ($n = 20$)	Between-subjects experiment	—	Photos with landscapes	POMS-SF Evaluation of VR preference	EEG: alpha power Stroop test	↓Negative mood in POG ($p = 0.03$, $\eta_p^2 = 0.11$) ↑Recreational preferences for BS ($p < 0.01$)
5. Huang et al. [49], China	Total (N = 89): courtyard ($n = 29$); courtyard with trees ($n = 30$); courtyard with grass ($n = 30$)	Between-subjects experiment	Abbreviated MPA	Scenery	PANAS Evaluation of VR quality	SCL	↓SCL in grass and tree cond. ($p = 0.03$, $\eta_p^2 = 0.06$) ↑PA in grass and tree cond. ($p = 0.03$, $\eta_p^2 = 0.07$) ↑VR Quality
6. Kim et al. [50], South Korea	Total (N = 74): VR relaxation; biofeedback	Crossover design	VR serial subtraction task	Video of natural scenes with relaxing soundtrack	Korean version of STAI NRS for discomfort PANAS SDS EQ-5D-5L SSQ	EMG SCL ST HR/BVP RSP: amplitude HRV: IBI, VLF, LF, HF, LF/HF, NN50, pNN50, RMSSD, SDNN	↓EMG in biofeedback ($p = 0.01$) ↓LF/HF ($p = 0.02$) in VR ↑NN50 ($p = 0.02$) and pNN50 ($p = 0.01$) in VR

Table 1. Cont.

Author and Place	Sample Size	Design	Stressor	VR Task	Subjective Tools	Objective Tools	Main Findings
7. Mostajeran et al. [51], Germany	Total (N = 34): VR urban and forest; indoor control	Within-subjects experiment	Arithmetic task	Urban or forest environment (slideshows or 360° videos)	STADI-S POMS SSSQ PSS IPQ SSQ	HR SCL	↑NA in video urban cond. ($p = 0.03$, $\eta_p^2 = 13$) ↑Sense of presence in video ($p < 0.001$, $\eta_p^2 = 0.70$) and in forest cond. ($p < 0.001$, $\eta_p^2 = 0.29$) ↑Simulator sickness scores ($p < 0.001$, $d = 0.63$) ↓SCL in photo slideshow ($p < 0.01$, $\eta_p^2 = 0.21$) ↓Cognitive test errors ($p = 0.004$, $\eta_p^2 = 0.22$) and ↑correct answers in forest cond. ($p < 0.001$, $\eta_p^2 = 0.29$)
8. Pretsch et al. [52], Austria	Total (N = 52): REALEX ($n = 31$), Video streaming ($n = 21$)	Between-subjects experiment	—	Videos of landscapes	VAS for emotion and relaxation PANAS DASS-21 UCL Presence Questionnaire	—	↑Relaxation ($p = 0.002$, $d = 0.62$) and ↓DASS ($p < 0.001$, $d = 0.84$) in REALAX
9. Tinga et al. [53], Netherlands	Total (N = 60): VR-BF ($n = 20$), control VR-BF-placebo ($n = 20$), control no-BF ($n = 20$)	Experiment	Arithmetic task	Meditation task based on Buddhist practices	VAS for tension and relaxation VAS for pleasantness and relaxation	HR HRV: RMSSD EEG: alpha and theta power, theta to alpha ratio	↓Subjective and objective arousal (HR, RMSSD and theta to alpha ratio) in control VR-BF-placebo ($p = 0.04$, $\eta_p^2 = 0.28$)
10. Vaquero-Blasco et al. [54], Spain	Total (N = 20): VR test group ($n = 10$); control group ($n = 10$)	Experiment	Computerized MIST	Chromotherapy room	One-item PSS Evaluation of VR experience	EEG: RG	↓Stress for all groups ($p < 0.05$) ↑VR experience
11. Vaquero-Blasco et al. [55], Spain	Total (N = 23): Aurora borealis, space, beach, cascade cave	Experiment	Computerized MIST	4 landscapes	One-item PSS Evaluation of VR experience	EEG: RG	↓Stress for all groups ($p < 0.001$) ↑VR experience
12. Villani and Riva [35], Italy	Total (N = 36): VR ($n = 12$), AU ($n = 12$), video ($n = 12$)	Between-subjects design	—	“ESCAPE” park with therapy approaches	MSP STAI-S	HR	↓HR in VR ($p < 0.05$) ↓Anxiety in Video guided sessions ($p < 0.001$)
13. Wang et al. [56], China	Total (N = 96): GR1 ($n = 15$), GR2 ($n = 13$), GR3 ($n = 12$), GR4 ($n = 14$); GR5 ($n = 12$); GR6 ($n = 15$); GR7 ($n = 15$);	Between-subjects experiment	TSST	Forest environments	BPOMS	DBP and SBP HR Salivary Amylase	↓TMD ($p < 0.05$) except GR 3 ↓DBP and SBP in GR 5 and 6 ($p < 0.05$) ↓DBP in GR 3 and 4 ($p < 0.05$) ↑Amylase in GR 4 ($p < 0.05$)

Table 1. Cont.

Author and Place	Sample Size	Design	Stressor	VR Task	Subjective Tools	Objective Tools	Main Findings
14. Yeom et al. [57], South Korea	Total (N = 27): non-green wall, small and large green wall	Crossover experiment	—	Residential space with a green wall	STAI-S	HRV: SDNN, RMSSD SCL EEG:RA, RHB, Mental stress and fatigue	↓Anxiety in small green wall (p < 0.01) ↑RA in P7, O1 (p < 0.05), P8 (p < 0.01) in small green wall ↓Mental stress and fatigue in small green wall (p < 0.05) ↓SCL in small green wall (p < 0.01)
15. Yin et al. [58], USA	Total (N = 30): 4 types (3 biophilic and 1 control non-biophilic cond.)	Crossover design	—	Indoor biophilic environments	Likert scale for stress and connection	DBP and SBP HR HRV: RMSSD SCL Stroop test AU test for creativity Eye tracking	↓SBP and DBP in biophilic cond. ↓HR in biophilic cond. ↑Creativity scores in AU test in biophilic cond. ↑Stroop test performance in biophilic cond. ↑Time spent at biophilic elements (eye tracking) ↑Connection with nature
16. Yin et al. [59], USA	Total (N = 100): Non-biophilic (n = 25), indoor Green (n = 25), outdoor View (n = 25), combination (n = 25)	Between-subjects experiment	VR memory and arithmetic tasks	Offices with different biophilic elements	STAI-6 Likert scale for stress	HRV: RMSSD, LF/HF HR SCL DBP and SBP	↓STAI in all four cond. ↓SBR and DBP in biophilic cond. ↑RMSSD in biophilic cond. ↑Chance of HR and RMSSD recovery in biophilic cond.

Note. ↓ decrease, ↑ improvement. AU, audio; AU test, Alternative Uses test; BP, blood pressure; BPOMS, Brief Profile of Mood States; BS, blue space; CG, closed green space; CIQ, Cognitive Interference Questionnaire; Cond., condition(s); DASS-21, Depression Anxiety Stress Scales; DBP, diastolic blood pressure; ECG, electrocardiogram; EMG, electromyography; EQ-5D, not explained in paper; GR, group; GrS, grey space; HF, high-frequency spectrum; HMD, head-mounted display; HR, heart rate; HR/BVP, heart rate/blood vessel pressure; HRV, heart rate variability; HRV-BF, standard heart rate variability biofeedback treatment; IBI, inter-beat interval; IPQ, Igroup Presence Questionnaire; LF, low-frequency spectrum; LF/HF ratio, low to high frequency ratio; ln, natural logarithm; MIST, Montreal imaging stress task; MPA, Markus and Peters arithmetic test; MRJPQ, Modified Reality Judgment and Presence Questionnaire; MSP, Mesure du Stress Psychologique Questionnaire; NA, negative affect; NN50, number of interval differences of successive normal-to-normal; NRS, 0–100 Numeric Rating Scale; nu, normalized units; OG, open green space; O1, occipital lobe in the left hemisphere; PANAS, PA, positive affect; Positive and Negative Affect Schedule; PCG, partly closed green space; pNN50, percentage of NN50; POG, partly open green space; POMS, Profiles of Mood States; POMS-SF, Profile of Mood States; PSS, Perceived Stress Scale; PSS-10, Perceived Stress Scale-10; P7, parietal lobe of the left hemisphere; P8, parietal lobe of the right hemisphere; RA, relative alpha power; RG, relative gamma defined as the power ratio between gamma and slow rhythms (alpha and theta); RLB, relative low beta power; RMSSD, root mean square of successive differences between normal heartbeats; RSP, respiration; SBP, systolic blood pressure; SCL, skin conductance level; SCR, skin conductance response; SDNN, standard deviation of the normal-to-normal interval; SDS, Sheehan’s Disability Scale; SMS, State Mindfulness Scale; SSQ, Simulator Sickness Questionnaire; SSSQ, Short Stress State Questionnaire; ST, skin temperature; STADI-S, State-Trait Anxiety Depression Inventory-State; STAI/STAI-S, State-Trait Anxiety Inventory; STAI-X1, State-Trait Anxiety Inventory- X1; STAI-6, short-form of State-Trait Anxiety Inventory; Stroop test, Stroop color–word test; TMD, total mood disturbance; TOT, total HRV power; TSST, Trier Social Stress Test; TWA, T-wave amplitude; VAS, Visual Analogue Scale; VLF, very-low-frequency band; VR-BF, VR-based heart rate variability biofeedback treatment; VVR, Value of VR Questionnaire.

3. Results

3.1. Search Outcome

Based on the inclusion and exclusion criteria, first the review authors independently screened the titles and abstracts of all relevant articles. Next, full-text versions of all potentially eligible articles were evaluated independently by the review authors to define whether all inclusion criteria were met. External experts would have been consulted to achieve a consensus in case of disagreement. However, this was not the case for the current review.

In total, 22,312 records were retrieved. Additionally, three studies were identified from the reference lists of previously published literature reviews. However, these studies were excluded because they did not fulfill the relevant criteria. After removing duplicates, 22,143 records were left for screening. Next, titles and abstracts were assessed and 22,064 were excluded, leaving 79 potentially relevant articles. From these studies only 44 articles were considered finally for full-text review. Screening of the full-text articles indicated that 28 did not fulfill the inclusion criteria, leaving 16 studies for this literature review. Figure 1 tracks the selection process of the relevant studies utilizing a modified version of the PRISMA flow diagram [60].

3.2. Study Results

3.2.1. Place of Study and Year

The review included studies that were conducted in Europe (50%), in Asia (31.3%) and in the USA (18.8%). All selected studies were published in scientific journals during the decade 2011–2021. Only a small fraction of the studies (12.5%) were conducted in the first half of the decade (i.e., 2011–2016), while the majority of them were carried out during 2017–2021 (87.5%).

3.2.2. Sample Size and Population Characteristics

The sample size of the extracted studies varied widely, from 18 participants [46] to 120 participants [48]. All the participants were healthy adult volunteers with ages ranging from 18 to 59. The prospective participants were screened to ensure that they did not suffer from any health issues or mental disorders, and that they did not receive any stress treatment or other medication therapies (62.5% of the studies) [31,47,50,52–56,58,59]. However, one study selected participants only if they reported a high stress level [35], and 31.3% of the studies did not follow any screening process at all [46,48,49,51,57].

3.2.3. Main Aim and Design

Fifteen studies examined the effectiveness of a VR protocol to reduce stress levels in the participants. Although one study [47] did not report explicitly that it focused on stress reduction, the authors included objective and subjective measures that are commonly used for stress assessment. For this reason, this study was considered for further analysis. In these studies, additional outcomes were assessed apart from stress reduction. In particular, in their study, Anderson et al. [46] evaluated VR natural settings for improving mood. Furthermore, the study of Gao et al. [48] examined the individual preferences for various urban environments. In their study, Mostajeran et al. [51] examined the impact of VR exposure on mood and cognition. Moreover, Pretsch et al. [52] assessed the efficiency of VR applications for the prevention of anxiety and depression among employees. In the same direction, Yin et al. [59] examined the effect of VR on anxiety levels during the recovery process. In their study, Yin et al. [58] assessed the creativity and attention of their participants.

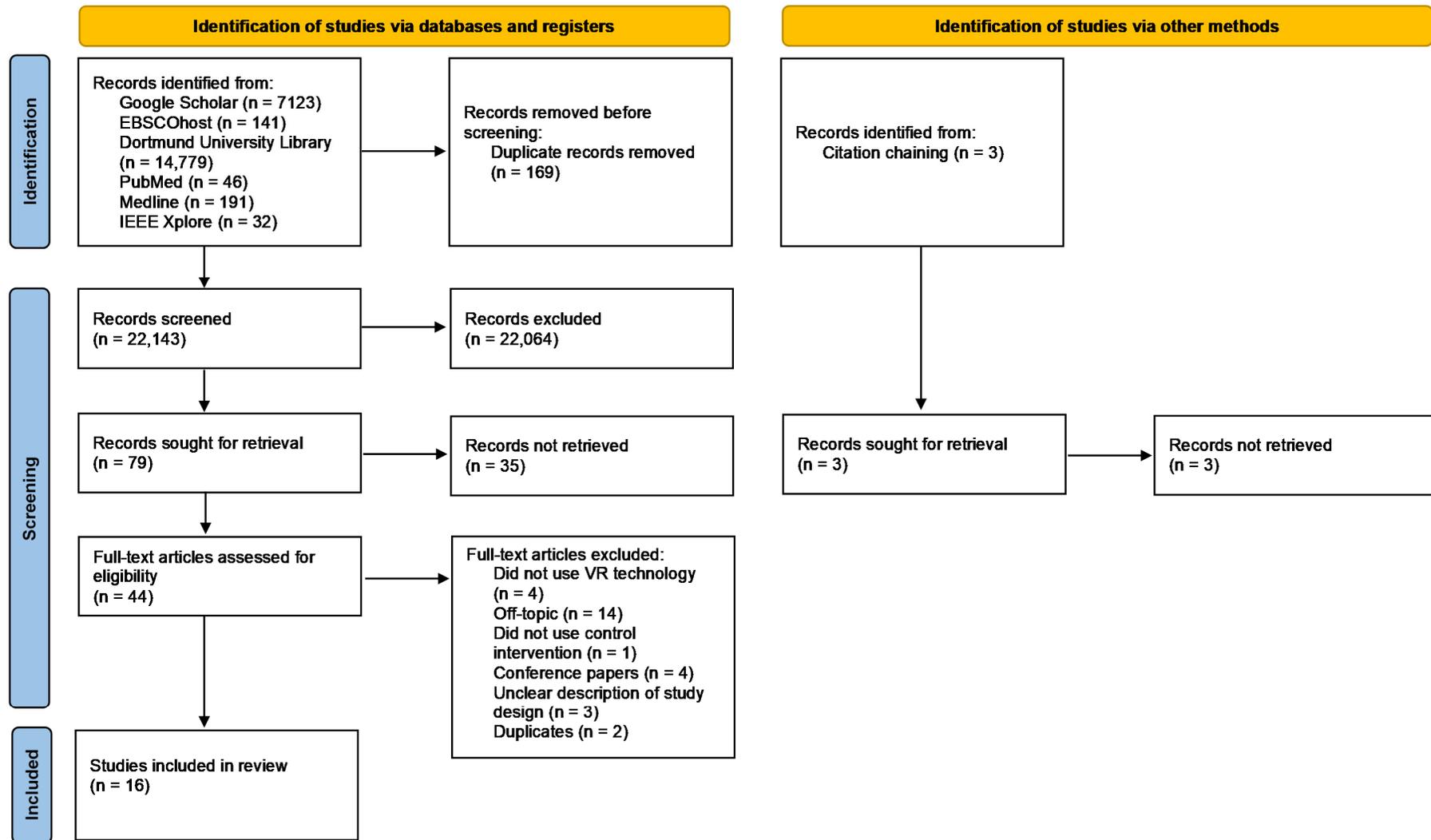


Figure 1. Search strategy for the inclusion and exclusion of studies based on a modified version of PRISMA flow diagram [60].

The majority of the studies utilized a between-subjects experimental design to study the effects of a VR protocol on the participants' stress level [31,35,47–49,52–56,59]. From these studies, three studies [53–55] did not describe in an explicit way that they used a between-subjects design. However, this was assumed from the context of the study. In addition, one research experiment applied a double-blind, randomized, laboratory procedure [47]. In their study, Villani and Riva [35] also carried out a between-subjects experiment, which consisted of six sessions of one hour each on different days. The first four sessions were conducted within two weeks. The last two sessions took part one month (first follow-up) and three months (second follow-up) later. Regarding the study design, two studies employed a within-subjects design [46,51]. The rest of the sample applied a randomized crossover design [50,57,58] similar to the within-subjects design, where the same participants underwent different relaxation phases. The studies of Kim et al. [50] and Yin et al. [58] carried out their experiments on two separate days following a randomized crossover design, while Yeom et al. [57] did not specify this information in their article.

3.2.4. Stressor

Before the beginning of the experimental session, which included either a relaxation phase or a control condition depending on the study's design, 68.7% of the studies set a protocol to increase participants' stress level. In particular, two studies utilized the Trier Social Stress Test (TSST) to induce stress [31,56]. Annerstedt et al. [31] designed a VR version of the TSST to be similar to the traditional one. This test mainly contains a public speech in front of a committee of specialists who are usually introduced as communication experts, followed by a public mental arithmetic task [61]. Two additional studies applied only the mental arithmetic component of the TSST [51,53]. Similarly, in their study, Anderson et al. [46] applied a stressing arithmetic test in front of the test operator. In the study of Huang et al. [49], the participants were asked to complete an abbreviated computerized version of the Markus and Peters arithmetic (MPA) test, a high effort mental mathematics task [62]. Furthermore, Kim et al. [50] induced dizziness and discomfort using VR videos with a high degree of movement, after which participants performed a subtraction task. In the study of Yin et al. [59], participants were exposed to a stressful virtual office with background noises, where they were requested to complete a memory and an arithmetic task, respectively. In their studies, Vaquero-Blasco et al. [54] and Vaquero-Blasco et al. [55] applied a computerized version of the Montreal imaging stress task (MIST) that contains a series of arithmetic tasks combined with social evaluative threat challenges [63]. Lastly, Blum et al. [47] utilized a computerized modified Stroop task, a test that induces mental overload as a result of cognitive conflict along with time-pressure effects [64]. The task was carried out before and after the treatment as it served as a stressor and a tool for measuring attentional resources.

As regards the stressor, 31.3% of the studies did not use a stressful task to produce psychophysiological arousal in their participants before the experimental phase. In their experiment, Gao et al. [48] perceived, however, a 2-h classroom immediately prior to participation as a natural stressor. In the remaining studies, the baseline measurement of the subjective and objective responses served for the stress assessment [35,52,57,58].

3.2.5. VR Task

In 13 studies the VR environments were used exclusively for the different relaxation tasks [35,46–49,51–58]. Only in three studies were both stress induction and relaxation performed in the VR environment [31,50,59]. In the vast majority of studies, natural landscapes [35,46,48,50,52,55], forest environments [31,51,56], and/or urban environments [48,49,51] were used as a means for relaxation. In addition, three studies focused on the design of office spaces [58,59] or the design of home-work residential spaces [57].

Although all the VR environments described in the studies were highly immersive, in most cases participants could only immerse themselves in the virtual world as observers, i.e., they could look around or move around. Only in two studies were the participants explicitly instructed not to move so as to avoid EEG artifacts [54,55]. However, in two

studies, the VR environment was designed so that environmental features would respond to the participant's behavior. In these studies, biofeedback tasks were used for relaxation; in one study, the breathing exercise was supported via the movement of a virtual breathing cloud [53], and in the other study, the cloudiness of the night sky changed in response to the biofeedback parameter [47]. Typically, VR relaxation tasks lasted between 5 and 15 min (mean: 8.3 min). An exception was the study of Villani and Riva [35], in which participants completed several sessions of relaxation exercises in different VR environments based on cognitive behavioral therapy.

In most studies, different VR environments were compared for their relaxation effects [31,35,46,48,51,53,55–59,65]. Three studies performed relaxation tasks [52] or biofeedback tasks [47,50] in both VR environments and on computer screens. Moreover, one study directly compared the relaxation effects between a real and identically designed virtual environment. This study involved the comparison of a real and virtual color therapy room, where identical chromotherapy tasks were performed for relaxation [54].

3.2.6. Subjective and Objective Tools for Psychophysiological Responses

Diverse instruments were applied for measuring the self-reported stress experience. The present review focuses only on the subjective and objective assessment tools for stress among healthy individuals. However, all assessment instruments that were used in the included studies, are listed in Table 1. Among the 16 studies, 8 different stress-related tools were utilized. The most commonly used tool for recording subjective stress was the State Anxiety subscale of the State-Trait Anxiety Inventory (STAI) [66], a self-report questionnaire that evaluates the temporary anxiety that can change depending on the surrounding environment [31,35,47,57,59]. Although the study of Kim et al. [50] utilized the Korean version of STAI, they did not specify if they used the full version of the questionnaire or the above-mentioned subscale. Another instrument that was utilized frequently, was the Perceived Stress Scale (PSS) [67], which measures the perception of stress [51,54,55]. The last two studies used, nevertheless, an adapted version of PSS so as to reduce response time and the interaction with the researchers [54,55]. In their study, Mostajeran et al. [51] also applied the State-Trait Anxiety Depression Inventory-State (STADI-S) [68] and the Short Stress State Questionnaire (SSSQ) [69]. The first tool records the current state of anxiety and depression of a person, whereas SSSQ measures the level of worry and anxiety after a given task. In the study of Pretsch et al. [52], the stress subscale of the Depression Anxiety Stress Scales (DASS-21) [70] was utilized to assess the presence of stress. Furthermore, Villani and Riva [35] evaluated one's perception of stress during the last three months through the Measure du Stress Psychologique Questionnaire (MSP) [71]. Other instruments were the Visual Analogue Scale (VAS) for subjective tension [53] and Likert scales for assessing self-reported stress level [31,58,59]. However, there were studies that did not measure stress directly, but they asked participants to rate their emotional state at that time via a self-report questionnaire [46,48,49,56].

The change in physiological responses from one study phase to the next during the course of the experiment was also quantified by means of physiological indices. Eleven studies measured the cardiac activity of their participants [31,35,46,47,50,51,53,56–59]. Indeed, alternations in the cardiac component describe a complex interplay between the sympathetic and parasympathetic branches of the ANS, which is triggered from external or internal changing conditions [72]. Furthermore, skin conductance was evaluated in seven studies [46,49–51,57–59]. This physiological parameter is controlled by the ANS [73], as it measures the electrodermal activity in the sweat glands and can be activated by exposure to a stressful event. Five studies evaluated participants' electrical activity in the brain [48,53–55,57], which is an objective indicator of physiological arousal in individuals [74]. Two studies also evaluated salivary markers of stress, namely cortisol and amylase [31,56], which are associated with the function of ANS [56,75]. Other physiological parameters for stress evaluation were electromyography, respiration, and skin temperature [50]. However, one study did not evaluate the physiological reactions of their participants [52].

3.2.7. User Experience

In the header subjective tools of Table 1, the questionnaires that described users' experience of VR were also included. Eight studies evaluated their users' experience regarding VR via questionnaires. In particular, in their study, Anderson et al. [46] utilized the Modified Reality Judgment and Presence Questionnaire (MRJPQ) [7,76] to assess the extent to which participants felt they were "present" in the VR environment, experienced the situation as real, and had an emotional impact. Furthermore, the participants filled out the Value of VR Questionnaire (VVR) [46] to assess how valuable they perceived VR. In their experiment, Gao et al. [48] asked their participants to indicate their preferences concerning the environment while wearing VR glasses through a "Yes/No/Hard to say" response. Huang et al. [49] evaluated the quality of the VR environment, but they did not provide further specification about the used instrument. In their study, Mostajeran et al. [51] used the Igroup Presence Questionnaire (IPQ) [77] to capture the sense of presence in VR and, also, the Simulator Sickness Questionnaire (SSQ) [78] to identify symptoms that occurred from VR exposure. Moreover, Pretsch et al. [52] used the UCL Presence Questionnaire [79] to measure their respondents' perceived feeling of presence in VR. In the studies of Vaquero-Blasco et al. [54] and Vaquero-Blasco et al. [55], the participants completed a survey to assess three dimensions of the VR solution: comfort, level of immersion, and their general experience. Lastly, Yin et al. [58] captured their respondents' feeling of connection with VR nature. Nevertheless, 50% of the sample did not assess the aspect of user experience at all [31,35,47,50,53,56,57,59].

3.2.8. Main Findings and Limitations

Nine studies indicated a significant positive effect of VR interventions either on perceived stress [52,54,55] and anxiety state [47,57,59] or on their participants' emotions [48,49,56]. Among these studies, two studies improved, nevertheless, subjective scores in the control condition apart from those in intervention groups [54,59]. Moreover, in their study, Tinga et al. [53] induced greater subjective arousal reduction in the control VR biofeedback (BF) placebo group than in the VR respiratory BF group. However, five studies did not report an effect of the VR intervention on stress-related questionnaires [31,46,50,51,58]. Lastly, Villani and Riva [35] showed a significantly higher decrease in state anxiety among participants in video- than in VR- and audio-guided sessions. On physiological levels, it was indicated that VR treatments had a significant positive effect on cardiac activity [35,46,50,56,58,59]. Furthermore, Annerstedt et al. [31] showed a reduction in cardiac activity in VR conditions and a control group. On the other hand, salivary cortisol decreased only in VR conditions, as concerns the same study. Tinga et al. [53], in their study, obtained a significant improvement in cardiac and brain indices only in the control VR-BF-placebo condition. Moreover, stress level evaluated by the EEG measurements decreased effectively in the study of Yeom et al. [57]. Electrodermal activity quantified by skin conductance level decreased in three studies [46,49,51,57]. Lastly, four studies did not report a significant effect of VR on stress-related physiological parameters [47,48,54,55]. However, Kim et al. [50] showed reduced muscle activity among participants in the biofeedback condition, which did not involve VR.

As regards the dimension of user experience, the studies included in the current review reported a positive experience overall. In detail, Anderson et al. [46] showed a higher mood impact and scene quality in both natural environments. Furthermore, the respondents agreed that one would benefit from VR technology and it could enhance people's relaxation ability. In the study of Gao et al. [48], participants indicated their preferences for an open space environment with prominent water elements and some greenery. In their experiment, Huang et al. [49] showed a positive experience with VR overall. They reported, however, symptoms related to VR exposure, such as slightly blurred vision and mild nausea. Mostajeran et al. [51] indicated a higher sense of general presence and experienced realism in video than in slideshow conditions ($p < 0.001$, $\eta_p^2 > 0.30$). Furthermore, the participants indicated high sense of spatial presence in videos and in the forest environment ($p < 0.01$, $\eta_p^2 > 0.20$) as well as high involvement in forest scene videos

($p < 0.001$, $\eta_p^2 > 0.50$). Although the feeling of presence was high, the respondents reported increased symptoms of simulator sickness. In the studies of Vaquero-Blasco et al. [54] and Vaquero-Blasco et al. [55], the participants assessed their general VR experience as positive and, also in terms of comfort and immersion. Lastly, Yin et al. [58] described a higher level of connection with biophilic elements than with natural analogue components. Nonetheless, only Pretsch et al. [52] reported a tendency showing that people who experienced VR might have had a higher sense of presence compared to the control condition (i.e., conventional relaxation video).

In this review, 75% of the included studies indicated possible limitations of their research work [31,47–52,55–59]. The most common limitations were related to methodological issues of the experiments, such as the lack of additional comparison groups, the quality of measurement tools or the need for further assessment instruments, issues regarding the experimental design and setup, the absence of evaluation of VR factors, and the lack of specific therapeutic activities in VR environments. Other limitations referred to restricted generalizability due to a homogeneous sample, the lack of longitudinal effects, or questionable long-term changes and sample small size. However, 25% of the sample did not discuss their study limitations [35,46,53,54].

3.3. Methodological Quality

The assessment of methodological quality for the study sample is presented in Table 2. MINORS scores ranged from 14 to 20 out of 24 for the comparative studies with a mean score of 17.5. Almost all studies received a score of 0 for the category regarding the inclusion of unbiased assessment of the study endpoint, except for the study of Blum et al. [47]. In addition, the included studies had low scores in the categories of prospective calculation of the study sample and baseline equivalence of comparison groups. In sum, the overall quality of the studies was considered good by the authors on a spectrum of excellent, good, fair, and poor.

Table 2. Methodological assessment of the study sample.

Author (Year)	MINORS Score (Raw)	Overall MINORS (%)
Anderson et al. [46]	16/24	66.6
Annerstedt et al. [31]	18/24	75
Blum et al. [47]	19/24	79.1
Gao et al. [48]	20/24	83.3
Huang et al. [49]	18/24	75
Kim et al. [50]	14/24	58.3
Mostajeran et al. [51]	18/24	75
Pretsch et al. [52]	19/24	79.1
Tinga et al. [53]	17/24	70.8
Vaquero-Blasco et al. [54]	16/24	66.6
Vaquero-Blasco et al. [55]	17/24	70.8
Villani and Riva [35]	16/24	66.6
Wang et al. [56]	18/24	75
Yeom et al. [57]	18/24	75
Yin et al. [58]	18/24	75
Yin et al. [59]	18/24	75
Mean Scores	17.5/24	75%

4. Discussion

This literature review aimed to explore the advances in stress management interventions utilizing VR technologies in healthy adults without psychopathological conditions. Sixteen research studies that employed VR systems for ameliorating stress were identified and considered for further analysis. While the modest number of the analyzed studies indicates a developing research area, the inclusion of more recent publications (i.e., after 2017) suggests that there is a growing interest in the field of VR applications for stress man-

agement. Recently, technology-enhanced healthcare approaches appear to have become more beneficial in terms of the care process, user experience, and costs [80]. In our study sample, eight studies (50%) reported a positive effect of the VR application employed on self-reported stress. Although half of the studies suggested a positive change in the primary outcome, one could say that this number highlights the heterogeneity of the methods of measurement and their produced effects. The review reveals, indeed, that the studies utilized diverse stress assessment instruments, which may render the identification of standardized or dominant experimental regimes for stress management in VR challenging. This variety may also imply that synthesizing and comparing study results (i.e., stress ratings) is very difficult. Previous research has also identified the same methodological problem regarding the different subjective questionnaires, which shows that rigorous testing protocols have not yet been established [81]. This fact can be linked to the broad definition attributed to the term “stress”, which usually refers not only to a person’s perception of a particular situation as upsetting or threatening, but also covers other factors, such as the emotional state of an individual, vulnerability, and coping resources [82]. As a result, researchers tend to measure only particular aspects of stress, such as emotional reactivity, ignoring factors that are equally important to capture the impact of VR interventions. To embrace different approaches regarding the definition of stress, future research should see stress in humans as a whole-person response [83], including psychological and physiological changes in their measurements.

This notion is also supported by the review findings that suggested a positive change in the physiological indices, including cardiac or brain activity, and cortisol and electrodermal activity (11 studies; 68.75%). The assessment of particular stress biomarkers could offer many advantages in future research, as the multidimensional nature of stress underlines the need for adopting a method depending on several modalities [84]. To be specific, such measures will allow researchers to identify their main outcomes in a more accurate way and simultaneously consider individual differences in stress susceptibility and relaxation mechanisms [38]. In line with this, several inherent and individual acquired factors, such as age, health status, and personality, can influence the physiological responses to stress as well as an individual’s ability to activate their own resources and deal with challenges. By understanding the interplay between individual characteristics and physiological traits, it would be possible to directly associate physiological outcomes with self-rating scales for stress and to better interpret, in turn, the induced effects from VR interventions. Hence, the development and implementation of common protocols for VR applications could help researchers address this major issue. In the future, selecting and combining data elements from various investigations may increase the impact of the results or expand the population to which the study results can be generalized, and accelerate knowledge growth [85].

From the examined studies that evoked an effect either on perceived stress or on physiological parameters, VR was mainly used in two ways to promote stress management in healthy populations. The majority of the authors (68.75%) employed immersive natural landscapes or resting indoor environments with biophilic elements to explore the restorative effects of VR on participants’ stress [31,46,48–50,52,55–59]. Generally, nature is considered to have a positive impact on human health. This is scientifically supported by previous research, which has pointed out the “added benefit” to mental health from natural environments and, also, their ability to promote recovery from stress [86–88]. This preference for green spaces can be thoroughly explained by well-known theories that focus on the importance of nature to restore individual’s mental and physical strengths. Ulrich’s stress reduction theory (SRT) [73,89,90] emphasizes the physical and emotional advantages of exposure to green spaces and their effect on mitigating stress reactions. In particular, a natural environment with dense vegetation or water elements, which is perceived as unthreatening and safe, can activate a positive emotional reaction engaging processes that facilitate wakefully relaxed attention, and reduced autonomic and somatic responses. Studies on natural scenes have shown, in fact, that stressed individuals can reduce their tension via the observation of natural elements, which also involves lower levels of negative affect

and quicker physical recovery from stress [34,89,90]. Similarly, Kaplan's attention restoration theory (ART) [89] is concerned with natural spaces and proposes that nature enables the restoration of attention capacities, which would otherwise be depleted by demanding, effortful activities. According to ART, natural environments owe their regenerative effect to four main qualities: (a) they are *fascinating* and attract involuntary attention without exploiting cognitive resources, (b) they offer a feeling of *being away*, (c) they give the impression of *extent and variety*, and (d) they are *compatible* with human existence. It seems that such preferences have their origins in evolutionary adaptive behaviors that were earlier essential for ensuring individual's survival and well-being. While immersive natural scenes appear to be frequently used in VR interventions, this fact does signal to future scientists that this area is a valuable starting point for proving further VR interventions' effectiveness on stress management. Generally, integrating natural elements into VR systems or combining them with other activities may be a promising tool for facilitating positive changes in subjective stress level and stress-related biomarkers.

In the present review, the combination of VR with heart rate variability biofeedback (HRV-BF) was also interesting. In their study, Blum et al. [47] conducted a single session of HRV-BF for a short duration, where the participants were requested to practice a slow diaphragmatic breathwork guided by auditory instructions. In the VR biofeedback condition, the individuals also experienced a virtual beach scenery. The authors argued that the use of standard HRV-BF demands the involvement of self-regulatory processes and increased attentional resources, which may add to the complexity of the task and may cause users' demotivation to continue the training. To overcome this barrier, they decided to embed biofeedback in a virtual natural setting that is enjoyable, offers meaningful biofeedback elements, and promotes involuntary attention toward the environment. Their results highlighted the positive changes on anxiety scores and relaxation self-efficacy. The positive and promising outcomes of such systems can also be identified in other studies. For instance, Weerdmeester et al. [90] showed in their pilot study that DEEP, a novel VR biofeedback game that involves deep diaphragmatic breathing, could effectively reduce physiological arousal that was being produced by an intense stressor. Moreover, in their study, Bernaerts et al. [91] indicated the positive effect of a VR application on reducing stress and anxiety in a clinical pediatric hospital, comprising among others breathing exercises and minigames with interactive animations and objects. In recent years the development and implementation of serious game–biofeedback applications to promote self-management and mental well-being has been growing [92,93] and may be the future in VR interventions for stress management. However, these applications with game elements should be further examined for their effectiveness in laboratory premises as well as in mental health interventions.

These results uncover VR systems' flexibility to be combined with other elements, such as biofeedback, or to be integrated into other concepts with a more traditional psychological background in order to produce significant psychophysiological effects. Among the retrieved studies, the paper of Villani et al. [35] has attracted attention as they employed immersive VR along with coping strategies derived from cognitive behavioral therapy approaches, such as self-monitoring, relaxation training, and guided imaginary experience. It is worth mentioning that their stress management protocol was held in different sessions, eliciting a significant reduction in cardiac activity after the sessions as well as in follow-up. Cognitive behavioral interventions and mindfulness-based exercises, which facilitate the active adaptation of responses to stresses, have been commonly adopted from prevention programs, for example, in occupational settings to reduce stress [24,25]. Employees can learn to manage adverse reactions to stressful events by bringing about a mental and/or physical state that is opposite to the psychophysiological arousal evoked by stress [25]. The goal is primarily to direct employees' attention to a stimulus and prevent distraction from irritating thoughts or the environment [94]. These cognitive mechanisms underlie two fundamental components: *attentional awareness* that makes possible attention regulation and *perspective shifting* that enables a person to reappraise beliefs and reactions with curiosity

and acceptance. An important outcome of the latter is *decentering*, a cognitive ability that inhibits the elaborative processing of experienced stressors and, thereby, decreases immersion and mental traveling to them [95,96]. Although these mental interventions can be beneficial to stressed individuals, they do also have some complexity, e.g., it might be hard at first to regulate negative feelings, that may cause frustration and negative feedback experiences. Pleasant virtual environments can promote users' awareness toward their responses, while they are practicing stress management techniques at their own pace and involuntarily focusing their attention on fascinating elements. Furthermore, immersive settings that are attractive and stimulate users' attention may be a way of increasing adherence to prevention programs; a main problem that concerns researchers in the area of prevention and population's mental health. Intervention adherence that reflects treatment engagement, is a key mechanism in psychological programs and is positively associated with intervention outcomes [97]. Therefore, the integration of VR applications into traditional intervention protocols could increase their effectiveness and enhance participants' adherence to them by creating stimulating experiences.

The present review underlines that VR systems can evoke a general positive change on the subjective and objective measurements in healthy adults and, consequently, could help them enhance their responses to stress. From a psychological point of view, at the basis of these applications is the user's sensation of leaving the current physical environment and being transported to the VR location [98]. The sense of presence can be influenced by several factors including technical-related aspects [99], intrapersonal factors [100], such as personality traits and social factors [98], and interaction with VR environments. Furthermore, another essential component of VR is immersion, which enables users to engage in digitally-recreated real-world environments and activities [101], simultaneously allowing them to experience if what they do there is similar to the real experience [102,103]. The ability of VR technology to recreate complex elements of real life makes presence and immersion salient factors for the relevant interventions [43]. In this way, VR-supported interventions can reconstruct personal experiences by motivating individuals to employ new techniques in a protected environment and to modify habitual reactions to stressful situations. In this sense, users can be exposed to a wide range of stress management techniques, practice them in different VR environments, and transfer them to real-life scenarios. Although VR characteristics can potentially define the quality of users' experiences and VR's effectiveness to evoke positive changes, only three studies of the sample (18.75%) used questionnaires to capture the feeling of presence after VR exposure [46,51,52], and two other studies (12.5%) explored the level of immersion [54,55]. One would say that this was one of the strongest commonalities within the investigated articles, which, however, should stimulate more research in the field, striving for well-designed interventions to facilitate a user's presence and immersion into VR activities.

While the methodological assessment of the studies is of primary importance for systematic reviews, it would be an omission not to emphasize the similar nature of the selected study designs. The study designs employed were mainly between-subjects experiments that were conducted in laboratories. This implies that the guidelines for randomized controlled trials were not followed. An exception to this was the study of Blum et al. [47] in which the authors conducted a double-blind, randomized, controlled, between-subjects experiment. This is perhaps an indication that strict study regimes for stress management among healthy populations in VR should be determined in the near future. The common nature of study designs may also explain why statistical assessment and comparisons of the main outcomes were difficult. In addition, the vast majority of the examined studies (93.75%) were conducted only in one session, except for the study of Villani and Riva [35]. Despite several studies providing evidence for the positive effects of VR on mental health, individuals might have returned later to stressed levels or might have failed to integrate the relaxation techniques into their daily routine, especially without continued support. One could mention that the lack of longer intervention periods and follow-ups could lead to questions about the quality of studies and their findings. However, the careful

investigation of non-randomized evidence can provide estimates of the direction and size of the produced effects [104]. This is particularly important for recently developed research fields such as VR, which demand evidence to move toward full-scale, repeatable, robust interventions [81]. In this respect, it is also encouraging that the overall quality of the review sample was good according to MINORS, indicating that VR applications can produce promising effects for stress management and the population's mental health. Hence, future studies are needed to include longer testing periods, and collect follow-up data so that they can increase the overall effectiveness of the research effort and can prove their novel nature.

Strengths and Limitations of the Systematic Review

The current literature review provides the reader with a detailed overview of the most recent VR applications aiming to reduce stress in healthy adult populations and help them develop adequate coping resources. The benefits of using VR systems for stress management can inspire scientists to develop and carry out evidenced-based programs for populations, for instance, with poor access to mental health services. However, there are a number of limitations of the present review that should be considered. Although the MINORS for the quality assessment of the sample was an asset for the review, the diversity of the interventions and instruments used for stress hampered the comparison of study findings, data-pooling, and meta-analysis. However, future authors are highly encouraged to apply such assessment tools, as they help with the methodological evaluation and critical appraisal of the included studies. Another limitation was that this review focused only on stress reduction, ignoring perhaps significant effects of VR on other outcomes, such as self-efficacy and mindfulness. As mentioned above, the study sample employed VR in different ways to fulfill diverse research aims, varying from testing nature environments to comparing VR interventions with non-technology-supported programs. Hence, if the authors had also analyzed factors directly related to relaxation, this might have partially distracted the reader from the main aim of the review. Following effects that are interwoven in stress management and in relaxation methods should be examined carefully in future research works. Moreover, the area of VR systems for stress management and prevention is growing rapidly. This may lead to the study of this field becoming quite challenging by demanding the use of reasonably strict search terms and protocols [81]. Thus, it is possible that articles have been unknowingly missed, despite multiple databases being screened. In line with this, another limitation was that the literature search was restricted to articles published in English only.

5. Conclusions

The improvement in mental health in the general population and the reduction in stress, especially during times of crisis, is one of the main challenges that healthcare systems face worldwide. Current technological developments in low-cost VR systems, aiming to generate a customized realistic world for the enhancement of stress management and the sense of relaxation, have been identified as a promising tool. Immersive VR has the potential to be systematically used in clinical and non-clinical practice in the coming years. However, the question of what are the current advances in VR applications for stress management among healthy adults still persists. This systematic review highlights the immediate need for evidence-based VR interventions that embrace nature elements and concepts derived from traditional treatment approaches, such as cognitive behavioral therapy techniques, and/or gaming elements (e.g., biofeedback). VR applications and activities with fascinating environments can enhance individuals' resources and improve their responses to stress. Moreover, they can be an effective medium for learning and applying methods for stress management in real-life situations. The integration of VR systems into stress prevention programs may help to overcome some obstacles of face-to-face interventions and, also, may offer several benefits, such as increased adherence, accessible high-quality health services, and cost-effective methods for health prevention. The research work conducted so far in the field of VR and stress should set the ground for further research. In this sense,

future scientists should develop rigorous study protocols and examine VR dimensions that are crucial for increasing VR's positive effects on stressed individuals. Therefore, special attention should be paid to the development of theory-driven VR interventions and the evaluation of their long-term effects compared to other preventive programs. This will aim to fully meet mental health needs in the general population, irrespective of the surrounding conditions. Future researchers are empowered to grasp the opportunity that the current pandemic generated, and employ digital technologies for strengthening the population's health.

Author Contributions: Conceptualization, M.V. and G.R.; methodology, M.V.; data extraction, classification, and quality assessment, M.V.; G.R., J.D. and S.S. participated in the process as well; formal analysis, M.V. and G.R.; investigation, resources, M.V. and G.R.; data curation, M.V.; writing—original draft preparation, M.V., G.R. and J.D.; reviewing, M.V., G.R., J.D. and S.S.; visualization, M.V.; supervision, M.V.; project administration, M.V.; funding acquisition, G.R. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the German Ministry of Education and Research (BMBF) and from resources of the European Social Fund (ESF) under grant number 02L18A081 (Project title: Digitaler Engel) within the program “Future of Work: Working on and with people”.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cipresso, P.; Giglioli, I.A.C.; Raya, M.A.; Riva, G. The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature. *Front. Psychol.* **2018**, *9*, 2086. [CrossRef] [PubMed]
2. Rogers, S. The Year Virtual Reality Gets Real. 2019. Available online: <https://www.forbes.com/sites/solrogers/2019/06/21/2019-the-year-virtual-reality-gets-real/> (accessed on 12 September 2021).
3. Sutherland, I.E. *The Ultimate Display. Multimedia: From Wagner to Virtual Reality*; Norton: New York, NY, USA, 1965.
4. Slater, M.; Wilbur, S. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence Teleoper. Virtual Environ.* **1997**, *6*, 603–616. [CrossRef]
5. De Carlo, A.; Carluccio, F.; Rapisarda, S.; Mora, D.; Ometto, I. Three uses of Virtual Reality in work and organizational psychology interventions—A dialogue between Virtual Reality and organizational well-being: Relaxation techniques, personal resources, and anxiety/depression treatments. *TPM Test. Psychom. Methodol. Appl. Psychol.* **2020**, *27*, 129–143. [CrossRef]
6. Slater, D. Social relationships and identity online and offline. In *Handbook of New Media: Social Shaping and Consequences of ICTs*; SAGE Publications: Thousand Oaks, CA, USA, 2002; pp. 533–546.
7. Witmer, B.G.; Singer, M.J. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence Teleoper. Virtual Environ.* **1998**, *7*, 225–240. [CrossRef]
8. Johnson-Glenberg, M.C. The necessary nine: Design principles for embodied VR and active stem education. In *Learning in a Digital World*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 83–112.
9. Schuemie, M.J.; van der Straaten, P.; Krijn, M.; van der Mast, C.A. Research on presence in virtual reality: A survey. *Cyber. Psychol. Behav.* **2001**, *4*, 183–201. [CrossRef] [PubMed]
10. Kleiber, C.; Harper, D.C. Effects of distraction on children's pain and distress during medical procedures: A meta-analysis. *Nurs. Res.* **1999**, *48*, 44–49. [CrossRef]
11. McCaffery, M.; Pasero, C. *Pain Clinical Manual*; Mosby: St. Louis, MO, USA, 1999.
12. Wiederhold, M.D.; Gao, K.; Wiederhold, B.K. Clinical use of virtual reality distraction system to reduce anxiety and pain in dental procedures. *Cyberpsychol. Behav. Soc. Netw.* **2014**, *17*, 359–365. [CrossRef]
13. Sharar, S.R.; Miller, W.; Teeley, A.; Soltani, M.; Hoffman, H.G.; Jensen, M.P.; Patterson, D.R. Applications of virtual reality for pain management in burn-injured patients. *Expert Rev. Neurother.* **2008**, *8*, 1667–1674. [CrossRef]
14. Vázquez, J.L.M.; Wiederhold, B.K.; Miller, I.; Lara, D.M.; Wiederhold, M.D. Virtual Reality Assisted Anesthesia (VRAA) during Upper Gastrointestinal Endoscopy: Report of 115 Cases—Analysis of Physiological Responses. *Surg. Res. Updates* **2017**. [CrossRef]
15. Vasquez, J.; Vaca, V.L.; Wiederhold, B.K.; Miller, I.; Wiederhold, M.D. Virtual reality pain distraction during gynecological Surgery—A report of 44 cases. *Surg. Res. Updates* **2017**, *5*, 12–16.
16. Association, A.P. Stress in America: A National Mental Health Crisis. Available online: <https://www.apa.org/news/press/releases/stress/2020/report-october> (accessed on 1 March 2022).

17. de Sousa, G.M.; Tavares, V.D.O.; de Meiroz Grilo, M.L.P.; Coelho, M.L.G.; de Lima-Araujo, G.L.; Schuch, F.B.; Galvao-Coelho, N.L. Mental Health in COVID-19 Pandemic: A Meta-Review of Prevalence Meta-Analyses. *Front. Psychol.* **2021**, *12*, 703838. [[CrossRef](#)] [[PubMed](#)]
18. Taelman, J.; Vandeput, S.; Spaepen, A.; van Huffel, S. Influence of Mental Stress on Heart Rate and Heart Rate Variability. In Proceedings of the 4th European Conference of the International Federation for Medical and Biological Engineering, Antwerp, Belgium, 23–27 November 2008; pp. 1366–1369.
19. Velana, M.; Rinkenauer, G. Developing a methodology to examine psychophysiological responses during stress exposure and relaxation: An experimental paradigm. In Proceedings of the ICHPS 2021: 23th International Conference on Health Psychology and Stress, Istanbul, Turkey, 8–9 November 2021.
20. McEwen, B.; Sapolsky, R. Stress and Your Health. *J. Clin. Endocrinol. Metab.* **2006**, *91*, E2. [[CrossRef](#)]
21. Monroe, S.M.; Harkness, K.L. Life stress, the “kindling” hypothesis, and the recurrence of depression: Considerations from a life stress perspective. *Psychol. Rev.* **2005**, *112*, 417–445. [[CrossRef](#)] [[PubMed](#)]
22. Phillips, L.J.; Francey, S.M.; Edwards, J.; McMurray, N. Stress and psychosis: Towards the development of new models of investigation. *Clin. Psychol. Rev.* **2007**, *27*, 307–317. [[CrossRef](#)] [[PubMed](#)]
23. Knoll, N.; Rieckmann, N.; Schwarzer, R. Coping as a mediator between personality and stress outcomes: A longitudinal study with cataract surgery patients. *Eur. J. Personal.* **2020**, *19*, 229–247. [[CrossRef](#)]
24. Van der Klink, J.J.; Blonk, R.W.; Schene, A.H.; van Dijk, F.J. The benefits of interventions for work-related stress. *Am. J. Public Health* **2001**, *91*, 270–276. [[CrossRef](#)]
25. Richardson, K.M.; Rothstein, H.R. Effects of occupational stress management intervention programs: A meta-analysis. *J. Occup. Health Psychol.* **2008**, *13*, 69–93. [[CrossRef](#)]
26. Delgado, C.; Upton, D.; Ranse, K.; Furness, T.; Foster, K. Nurses’ resilience and the emotional labour of nursing work: An integrative review of empirical literature. *Int. J. Nurs. Stud.* **2017**, *70*, 71–88. [[CrossRef](#)]
27. Ghawadra, S.F.; Abdullah, K.L.; Choo, W.Y.; Phang, C.K. Mindfulness-based stress reduction for psychological distress among nurses: A systematic review. *J. Clin. Nurs.* **2019**, *28*, 3747–3758. [[CrossRef](#)]
28. Cavanagh, K.; Strauss, C.; Cicconi, F.; Griffiths, N.; Wyper, A.; Jones, F. A randomised controlled trial of a brief online mindfulness-based intervention. *Behav. Res. Ther.* **2013**, *51*, 573–578. [[CrossRef](#)]
29. Heber, E.; Ebert, D.D.; Lehr, D.; Cuijpers, P.; Berking, M.; Nobis, S.; Riper, H. The Benefit of Web- and Computer-Based Interventions for Stress: A Systematic Review and Meta-Analysis. *J. Med. Internet Res.* **2017**, *19*, e32. [[CrossRef](#)] [[PubMed](#)]
30. Beukeboom, C.J.; Langeveld, D.; Tanja-Dijkstra, K. Stress-reducing effects of real and artificial nature in a hospital waiting room. *J. Altern. Complement. Med.* **2012**, *18*, 329–333. [[CrossRef](#)] [[PubMed](#)]
31. Annerstedt, M.; Jonsson, P.; Wallergard, M.; Johansson, G.; Karlson, B.; Grahn, P.; Hansen, A.M.; Wahrborg, P. Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiol. Behav.* **2013**, *118*, 240–250. [[CrossRef](#)] [[PubMed](#)]
32. Riva, G.; Bernardelli, L.; Browning, M.; Castelnuovo, G.; Cavedoni, S.; Chirico, A.; Ciproso, P.; de Paula, D.M.B.; Di Lernia, D.; Fernandez-Alvarez, J.; et al. COVID Feel Good-An Easy Self-Help Virtual Reality Protocol to Overcome the Psychological Burden of Coronavirus. *Front. Psychiatry* **2020**, *11*, 563319. [[CrossRef](#)] [[PubMed](#)]
33. Riva, G.; Bernardelli, L.; Castelnuovo, G.; Di Lernia, D.; Tuena, C.; Clementi, A.; Pedroli, E.; Malighetti, C.; Sforza, F.; Wiederhold, B.K.; et al. A Virtual Reality-Based Self-Help Intervention for Dealing with the Psychological Distress Associated with the COVID-19 Lockdown: An Effectiveness Study with a Two-Week Follow-Up. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8188. [[CrossRef](#)]
34. Beverly, E.; Hommema, L.; Coates, K.; Duncan, G.; Gable, B.; Gutman, T.; Love, M.; Love, C.; Pershing, M.; Stevens, N. A tranquil virtual reality experience to reduce subjective stress among COVID-19 frontline healthcare workers. *PLoS ONE* **2022**, *17*, e0262703. [[CrossRef](#)]
35. Villani, D.; Riva, G. Does interactive media enhance the management of stress? Suggestions from a controlled study. *Cyberpsychol. Behav. Soc. Netw.* **2012**, *15*, 24–30. [[CrossRef](#)]
36. Velana, M.; Rinkenauer, G. The Role of Modern Technology for the Prevention of Job-Related Stress and the Enhancement of Coping Strategies Among Nurses. In Proceedings of the 2nd International Conference on Future of Preventive Medicine and Public Health, Virtual, 24–25 March 2022.
37. Wind, T.R.; Rijkeboer, M.; Andersson, G.; Riper, H. The COVID-19 pandemic: The ‘black swan’ for mental health care and a turning point for e-health. *Internet Interv.* **2020**, *20*, 100317. [[CrossRef](#)] [[PubMed](#)]
38. Velana, M.; Rinkenauer, G. Individual-Level Interventions for Decreasing Job-Related Stress and Enhancing Coping Strategies Among Nurses: A Systematic Review. *Front. Psychol.* **2021**, *12*, 708696. [[CrossRef](#)] [[PubMed](#)]
39. Kanehira, R.; Ito, Y.; Suzuki, M.; Hideo, F. Enhanced relaxation effect of music therapy with VR. In Proceedings of the 14th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), Huangshan, China, 28–30 July 2018; pp. 1374–1378.
40. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann. Intern. Med.* **2009**, *151*, 264–269. [[CrossRef](#)]
41. Slim, K.; Nini, E.; Forestier, D.; Kwiatkowski, F.; Panis, Y.; Chipponi, J. Methodological index for non—Randomized studies (MINORS): Development and validation of a new instrument. *ANZ J. Surg.* **2003**, *73*, 712–716. [[CrossRef](#)] [[PubMed](#)]

42. Boutris, N.; Byrne, R.A.; Delgado, D.A.; Hewett, T.E.; McCulloch, P.C.; Lintner, D.M.; Harris, J.D. Is There an Association Between Noncontact Anterior Cruciate Ligament Injuries and Decreased Hip Internal Rotation or Radiographic Femoroacetabular Impingement? A Systematic Review. *Arthroscopy* **2018**, *34*, 943–950. [[CrossRef](#)] [[PubMed](#)]
43. Montana, J.I.; Matamala-Gomez, M.; Maisto, M.; Mavrodiiev, P.A.; Cavallera, C.M.; Diana, B.; Mantovani, F.; Realdon, O. The benefits of emotion regulation interventions in virtual reality for the improvement of wellbeing in adults and older adults: A systematic review. *J. Clin. Med.* **2020**, *9*, 500.
44. Edwards, D.; Burnard, P. A systematic review of stress and stress management interventions for mental health nurses. *J. Adv. Nurs.* **2003**, *42*, 169–200. [[CrossRef](#)]
45. Klein, A.; Taieb, O.; Xavier, S.; Baubet, T.; Reyre, A. The benefits of mindfulness-based interventions on burnout among health professionals: A systematic review. *Explore* **2020**, *16*, 35–43. [[CrossRef](#)]
46. Anderson, A.P.; Mayer, M.D.; Fellows, A.M.; Cowan, D.R.; Hegel, M.T.; Buckey, J.C. Relaxation with Immersive Natural Scenes Presented Using Virtual Reality. *Aerosp. Med. Hum. Perform* **2017**, *88*, 520–526. [[CrossRef](#)]
47. Blum, J.; Rockstroh, C.; Goritz, A.S. Heart Rate Variability Biofeedback Based on Slow-Paced Breathing With Immersive Virtual Reality Nature Scenery. *Front. Psychol.* **2019**, *10*, 2172. [[CrossRef](#)]
48. Gao, T.; Zhang, T.; Zhu, L.; Gao, Y.; Qiu, L. Exploring Psychophysiological Restoration and Individual Preference in the Different Environments Based on Virtual Reality. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3102. [[CrossRef](#)]
49. Huang, Q.; Yang, M.; Jane, H.-A.; Li, S.; Bauer, N. Trees, grass, or concrete? The effects of different types of environments on stress reduction. *Landsc. Urban Plan.* **2020**, *193*, 103654. [[CrossRef](#)]
50. Kim, H.; Kim, D.J.; Kim, S.; Chung, W.H.; Park, K.A.; Kim, J.D.K.; Kim, D.; Kim, M.J.; Kim, K.; Jeon, H.J. Effect of Virtual Reality on Stress Reduction and Change of Physiological Parameters Including Heart Rate Variability in People With High Stress: An Open Randomized Crossover Trial. *Front. Psychiatry* **2021**, *12*, 614539. [[CrossRef](#)]
51. Mostajeran, F.; Krzikawski, J.; Steinicke, F.; Kuhn, S. Effects of exposure to immersive videos and photo slideshows of forest and urban environments. *Sci. Rep.* **2021**, *11*, 3994. [[CrossRef](#)] [[PubMed](#)]
52. Pretsch, J.; Pretsch, E.; Saretzki, J.; Kraus, H.; Grossmann, G. Improving employee well-being by means of virtual reality–REALEX: An empirical case study. *Eur. J. Econ. Bus. Stud.* **2020**, *6*, 95–105.
53. Tinga, A.M.; Nyklicek, I.; Jansen, M.P.; de Back, T.T.; Louwerse, M.M. Respiratory Biofeedback Does Not Facilitate Lowering Arousal in Meditation Through Virtual Reality. *Appl. Psychophysiol. Biofeedback* **2019**, *44*, 51–59. [[CrossRef](#)] [[PubMed](#)]
54. Vaquero-Blasco, M.A.; Perez-Valero, E.; Lopez-Gordo, M.A.; Morillas, C. Virtual Reality as a Portable Alternative to Chromotherapy Rooms for Stress Relief: A Preliminary Study. *Sensors* **2020**, *20*, 6211. [[CrossRef](#)]
55. Vaquero-Blasco, M.A.; Perez-Valero, E.; Morillas, C.; Lopez-Gordo, M.A. Virtual Reality Customized 360-Degree Experiences for Stress Relief. *Sensors* **2021**, *21*, 2219. [[CrossRef](#)] [[PubMed](#)]
56. Wang, X.; Shi, Y.; Zhang, B.; Chiang, Y. The Influence of Forest Resting Environments on Stress Using Virtual Reality. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3263. [[CrossRef](#)]
57. Yeom, S.; Kim, H.; Hong, T. Psychological and physiological effects of a green wall on occupants: A cross-over study in virtual reality. *Build. Environ.* **2021**, *204*, 108134. [[CrossRef](#)]
58. Yin, J.; Arfaei, N.; MacNaughton, P.; Catalano, P.J.; Allen, J.G.; Spengler, J.D. Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality. *Indoor Air* **2019**, *29*, 1028–1039. [[CrossRef](#)]
59. Yin, J.; Yuan, J.; Arfaei, N.; Catalano, P.J.; Allen, J.G.; Spengler, J.D. Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environ. Int.* **2020**, *136*, 105427. [[CrossRef](#)]
60. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [[CrossRef](#)]
61. Kirschbaum, C.; Pirke, K.M.; Hellhammer, D.H. The ‘Trier Social Stress Test’—A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology* **1993**, *28*, 76–81. [[CrossRef](#)] [[PubMed](#)]
62. Peters, M.L.; Godaert, G.L.; Ballieux, R.E.; van Vliet, M.; Willemsen, J.J.; Sweep, F.C.; Heijnen, C.J. Cardiovascular and endocrine responses to experimental stress: Effects of mental effort and controllability. *Psychoneuroendocrinology* **1998**, *23*, 1–17. [[CrossRef](#)]
63. Dedovic, K.; Renwick, R.; Mahani, N.K.; Engert, V.; Lupien, S.J.; Pruessner, J.C. The Montreal Imaging Stress Task: Using functional imaging to investigate the effects of perceiving and processing psychosocial stress in the human brain. *J. Psychiatry Neurosci.* **2005**, *30*, 319–325.
64. Tulen, J.H.; Moleman, P.; van Steenis, H.G.; Boomsma, F. Characterization of stress reactions to the Stroop Color Word Test. *Pharm. Biochem. Behav.* **1989**, *32*, 9–15. [[CrossRef](#)]
65. Li, H.; Zhao, M.; Shi, Y.; Xing, Z.; Li, Y.; Wang, S.; Ying, J.; Zhang, M.; Sun, J. The effectiveness of aromatherapy and massage on stress management in nurses: A systematic review. *J. Clin. Nurs.* **2019**, *28*, 372–385. [[CrossRef](#)] [[PubMed](#)]
66. Spielberger, C.; Gorsuch, R.; Lushemne, R.; Vagg, P.; Jacobs, G. *Manual for the State-Trait Anxiety Inventory*, 2nd ed.; Consulting Psychologists Press: Palo Alto, CA, USA, 1983.
67. Cohen, S.; Kamarck, T.; Mermelstein, R. A global measure of perceived stress. *J. Health Soc. Behav.* **1983**, *24*, 385–396. [[CrossRef](#)] [[PubMed](#)]
68. Bergner-Köther, R. *Zur Differenzierung von Angst und Depression: Ein Beitrag zur Konstruktvalidierung des State-Trait-Angst-Depressions-Inventars (Vol. 18)*; University of Bamberg Press: Bamberg, Germany, 2014.

69. Helton, W.S.; Näswall, K. Short Stress State Questionnaire. *Eur. J. Psychol. Assess.* **2014**, *31*, 20–30. [[CrossRef](#)]
70. Lovibond, S.H.; Lovibond, P.F. *Manual for the Depression Anxiety Stress Scales*; Psychology Foundation: Sydney, Australia, 1995.
71. Tessier, R.; Lemure, L.; Fillion, L. *Mesure du Stress Psychologique MSP*; The Aviora: Tettngang, Germany, 1990.
72. McCraty, R.; Shaffer, F. Heart Rate Variability: New Perspectives on Physiological Mechanisms, Assessment of Self-regulatory Capacity, and Health risk. *Glob. Adv. Health Med.* **2015**, *4*, 46–61. [[CrossRef](#)]
73. Ulrich, R.S.; Simons, R.F.; Losito, B.D.; Fiorito, E.; Miles, M.A.; Zelson, M. Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* **1991**, *11*, 201–230. [[CrossRef](#)]
74. Hassan, A.; Qibing, C.; Tao, J. Physiological and psychological effects of gardening activity in older adults. *Geriatr. Gerontol. Int.* **2018**, *18*, 1147–1152. [[CrossRef](#)]
75. Ngampramuan, S.; Tungtong, P.; Mukda, S.; Jariyavilas, A.; Sakulisariyaporn, C. Evaluation of Autonomic Nervous System, Saliva Cortisol Levels, and Cognitive Function in Major Depressive Disorder Patients. *Depress. Res. Treat.* **2018**, *2018*, 7343592. [[CrossRef](#)] [[PubMed](#)]
76. Baños, R.M.; Botella, C.; Garcia-Palacios, A.; Villa, H.; Perpiña, C.; Alcañiz, M. Presence and Reality Judgment in Virtual Environments: A Unitary Construct? *Cyber. Psychol. Behav.* **2000**, *3*, 327–335. [[CrossRef](#)]
77. Schubert, T.; Friedmann, F.; Regenbrecht, H. The Experience of Presence: Factor Analytic Insights. *Presence Teleoper. Virtual Environ.* **2001**, *10*, 266–281. [[CrossRef](#)]
78. Kennedy, R.S.; Lane, N.E.; Berbaum, K.S.; Lilienthal, M.G. Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *Int. J. Aviat. Psychol.* **1993**, *3*, 203–220. [[CrossRef](#)]
79. Slater, M.; Usoh, M.; Steed, A. Depth of Presence in Virtual Environments. *Presence Teleoper. Virtual Environ.* **1994**, *3*, 130–144. [[CrossRef](#)]
80. Realdon, O.; Rossetto, F.; Nalin, M.; Baroni, I.; Cabinio, M.; Fioravanti, R.; Saibene, F.L.; Alberoni, M.; Mantovani, F.; Romano, M.; et al. Technology-enhanced multi-domain at home continuum of care program with respect to usual care for people with cognitive impairment: The Ability-Telerehabilitation study protocol for a randomized controlled trial. *BMC Psychiatry* **2016**, *16*, 425. [[CrossRef](#)]
81. Naylor, M.; Ridout, B.; Campbell, A. A Scoping Review Identifying the Need for Quality Research on the Use of Virtual Reality in Workplace Settings for Stress Management. *Cyber. Psychol. Behav. Soc. Netw.* **2020**, *23*, 506–518. [[CrossRef](#)]
82. Endler, N.S.; Parker, J.D. Stress and anxiety: Conceptual and assessment issues. *Stress Med.* **1990**, *6*, 243–248. [[CrossRef](#)]
83. Jones, T.L. Definition of Stress. In *Eating Disorders in Women and Children: Prevention, Stress Management, and Treatment*; Goodheart, K., Clopton, J.R., McComb, J.J., Eds.; CRC Press: Boca Raton, FL, USA, 2001; pp. 89–100.
84. Alberdi, A.; Aztiria, A.; Basarab, A. Towards an automatic early stress recognition system for office environments based on multimodal measurements: A review. *J. Biomed. Inform.* **2016**, *59*, 49–75. [[CrossRef](#)]
85. Cohen, M.Z.; Thompson, C.B.; Yates, B.; Zimmerman, L.; Pullen, C.H. Implementing common data elements across studies to advance research. *Nurs. Outlook* **2015**, *63*, 181–188. [[CrossRef](#)]
86. Hansmann, R.; Hug, S.-M.; Seeland, K. Restoration and stress relief through physical activities in forests and parks. *Urban For. Urban Green.* **2007**, *6*, 213–225. [[CrossRef](#)]
87. Bowler, D.E.; Buyung-Ali, L.M.; Knight, T.M.; Pullin, A.S. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* **2010**, *10*, 456. [[CrossRef](#)] [[PubMed](#)]
88. Barton, J.; Pretty, J. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environ. Sci. Technol.* **2010**, *44*, 3947–3955. [[CrossRef](#)] [[PubMed](#)]
89. Kaplan, S. The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol.* **1995**, *15*, 169–182. [[CrossRef](#)]
90. Weerdmeester, J.; van Rooij, M.; Harris, O.; Smit, N.; Engels, R.C.M.E.; Granic, I. Exploring the Role of Self-efficacy in Biofeedback Video Games. In Proceedings of the Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play, Virtual, 2–4 November 2020; pp. 453–461.
91. Bernaerts, S.; Bonroy, B.; Daems, J.; Sels, R.; Struyf, D.; Gies, I.; van de Veerdonk, W. Virtual Reality for Distraction and Relaxation in a Pediatric Hospital Setting: An Interventional Study With a Mixed-Methods Design. *Front. Digit. Health* **2022**, *4*, 866119. [[CrossRef](#)]
92. Fernández-Aranda, F.; Jiménez-Murcia, S.; Santamaría, J.J.; Gunnard, K.; Soto, A.; Kalapanidas, E.; Bults, R.G.; Davarakis, C.; Ganchev, T.; Granero, R. Video games as a complementary therapy tool in mental disorders: PlayMancer, a European multicentre study. *J. Ment. Health* **2012**, *21*, 364–374. [[CrossRef](#)]
93. Bingham, P.M.; Bates, J.H.; Thompson-Figueroa, J.; Lahiri, T. A breath biofeedback computer game for children with cystic fibrosis. *Clin. Pediatr.* **2010**, *49*, 337–342. [[CrossRef](#)]
94. Bellarosa, C.; Chen, P.Y. The effectiveness and practicality of occupational stress management interventions: A survey of subject matter expert opinions. *J. Occup. Health Psychol.* **1997**, *2*, 247–262. [[CrossRef](#)]
95. Lebois, L.A.; Papiés, E.K.; Gopinath, K.; Cabanban, R.; Quigley, K.S.; Krishnamurthy, V.; Barrett, L.F.; Barsalou, L.W. A shift in perspective: Decentering through mindful attention to imagined stressful events. *Neuropsychologia* **2015**, *75*, 505–524. [[CrossRef](#)]
96. Bishop, S.R.; Lau, M.; Shapiro, S.; Carlson, L.; Anderson, N.D.; Carmody, J.; Segal, Z.V.; Abbey, S.; Speca, M.; Velting, D. Mindfulness: A proposed operational definition. *Clin. Psychol. Sci. Pract.* **2004**, *11*, 230. [[CrossRef](#)]
97. Musiat, P.; Johnson, C.; Atkinson, M.; Wilksch, S.; Wade, T. Impact of guidance on intervention adherence in computerised interventions for mental health problems: A meta-analysis. *Psychol. Med.* **2022**, *52*, 229–240. [[CrossRef](#)] [[PubMed](#)]

98. Servotte, J.-C.; Goosse, M.; Campbell, S.H.; Dardenne, N.; Pilote, B.; Simoneau, I.L.; Guillaume, M.; Bragard, I.; Ghuysen, A. Virtual Reality Experience: Immersion, Sense of Presence, and Cybersickness. *Clin. Simul. Nurs.* **2020**, *38*, 35–43. [[CrossRef](#)]
99. Weech, S.; Kenny, S.; Barnett-Cowan, M. Presence and cybersickness in virtual reality are negatively related: A review. *Front. Psychol.* **2019**, *10*, 158. [[CrossRef](#)]
100. Weibel, D.; Wissmath, B.; Mast, F.W. Immersion in mediated environments: The role of personality traits. *Cyberpsychol. Behav. Soc. Netw.* **2010**, *13*, 251–256. [[CrossRef](#)] [[PubMed](#)]
101. Parsons, T.D. Virtual Reality for Enhanced Ecological Validity and Experimental Control in the Clinical, Affective and Social Neurosciences. *Front. Hum. Neurosci.* **2015**, *9*, 660. [[CrossRef](#)]
102. Kim, M.; Jeon, C.; Kim, J. A Study on Immersion and Presence of a Portable Hand Haptic System for Immersive Virtual Reality. *Sensors* **2017**, *17*, 1141. [[CrossRef](#)] [[PubMed](#)]
103. Slater, M.; Lotto, B.; Arnold, M.M.; Sánchez-Vives, M.V. How we experience immersive virtual environments: The concept of presence and its measurement. *Anu. Psicol.* **2009**, *40*, 193–210.
104. Higgins, J.P.; Thomas, J.; Chandler, J.; Cumpston, M.; Li, T.; Page, M.J.; Welch, V.A. *Cochrane Handbook for Systematic Reviews of Interventions*; John Wiley & Sons: Hoboken, NJ, USA, 2019.