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ORIGINAL ARTICLE

Mental healing through immersive play: An umbrella review

Franz Coelho[1,2] · **Ana Maria Abreu**[3]

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Abstract

This umbrella review explores the effects of Extended Reality (XR) and Game-Based Interventions (GBI) on anxiety, depression, and stress, covering augmented (AR), virtual (VR), and mixed reality (MR), along with serious games, gamification, game-based learning and training, exergames, and commercial video games. Following PRISMA and AMSTAR 2 guidelines, 201 articles were screened, with 16 reports selected (nine meta-analyses, six systematic reviews, and one scoping review). Findings highlight XR-GBI's potential as a promising, flexible, and replicable intervention, demonstrating significant preliminary mental health improvement across children, adolescents, adults, and older people. Regarding anxiety, VR aids preoperative and procedural anxiety, promotes distraction and relaxation, and supports VR exposure therapy (VRET), matching Cognitive Behavioral Therapy (CBT) effectiveness with higher engagement. For depression, VRET reduces symptoms, while VR exergames combining physical activity and engagement show strong antidepressant effects. Stress management remains less explored, though AR video games enhance cognitive and social well-being, and VRET alleviates stress symptoms. Despite the XR-GBI promise, research is still emerging, with publications only beginning to expand recently, few randomized controlled trials, and methodological limitations. From our findings, we highlight practical and theoretical implications by showing how XR-GBI rely on core technical features and proposing a five-pathway theoretical model (cognitive, emotional, bodily, social, and motivational) that systematizes their potential for mental health, guiding future design, evaluation, and research. Further research should also expand on AR, MR, gamification, game-based learning and training, biofeedback, neurophysiological assessment, and social dynamics, while integrating artificial intelligence, digital mental health literacy, and psychoeducation to enhance XR-GBI's impact.

Keywords Games · Extended Reality · Virtual Reality · Mental Health · Anxiety · Depression · Stress

1 Introduction

The rising prevalence of psychiatric conditions presents a global health challenge, affecting quality of life and productivity, and, while pharmacotherapy and psychotherapy remain primary treatments, alternative approaches are gaining attention (Jurek and Owczarek 2022; Remskar et al. 2024). In this context, extended reality (XR) and game-based intervention (GBI) serve as innovative mental health tools, enhancing therapy and intervention delivery through immersive and interactive environments (Baghaei et al. 2022; Bell et al. 2020).

XR encompasses augmented (AR), virtual (VR), and mixed realities (MR) and includes immersive technologies from local presence to telepresence, using mobile devices, projectors, head-mounted displays (HMD), and immersive caves (Rauschnabel et al. 2022). AR overlays digital content onto the real world without interaction between physical and virtual elements, VR creates fully immersive environments with simulated sensory input, and MR blends virtual and real elements into an interactive context where both can be integrated and manipulated interactively (Palmas and Klinker 2020). XR has been used to diagnose and

✉ Franz Coelho
s-fgcoelho@ucp.pt; franzgrc@gmail.com

Ana Maria Abreu
anamariablom@gmail.com

[1] Universidade Católica Portuguesa, Center for Interdisciplinary Research in Health (CIIS), Lisbon, Portugal

[2] Universidade Católica Portuguesa, Faculty of Health Sciences and Nursing (FCSE), Lisbon, Portugal

[3] Center for Psychological Research and Social Intervention (CIS_ISCTE), Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal

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treat mental health disorders, with technological advances enabling commercial solutions for professionals and patients, holding great potential to enrich the therapeutic experience (Pons et al. 2022). XR creates a supportive and low-risk space that encourages independent learning, sharpens essential abilities, and fosters confidence, making it particularly useful for sensitive, high-pressure settings such as mental health care (Hiley et al. 2025; Kaplan et al. 2021). Applied in healthcare, XR supports user behavior analysis, integrating biotechnology sensors, neurophysiological tools, and motion tracking for precise assessments (Adriana Cárdenas-Robledo et al. 2022).

GBI encompass a range of approaches, including serious games, gamification, game-based learning, game-based training, exergames, and commercial video games, all of which leverage playful and engaging processes to foster cognition, skill development, and behavioral change (Ferreira-Brito et al. 2019; Krath et al. 2021; López-Nava et al. 2022). Serious games are fully developed games designed not only for entertainment but also for other purposes, such as education, real-life simulation, and intervention to reduce mental health symptoms (Abt 1987; Deterding et al. 2011, 2013; Dewhirst et al. 2022; Min et al. 2022). In contrast, gamification does not involve full-fledged games but rather integrates game elements into non-game settings to create more engaging experiences (Coelho et al. 2024b; Deterding et al. 2011, 2013; Landers et al. 2018), involving therapeutic use for improving mental health and enhancing treatment effectiveness (Cheng and Ebrahimi 2023). Game-based learning integrates games into educational settings (Prensky 2001; Ragni et al. 2023; Van Eck 2015), transforming psychoeducation and mental health programs—such as social–emotional learning—into more engaging experiences that foster awareness and equip individuals with coping strategies for mental health (Lynn et al. 2024; Vogelaar et al. 2024). Game-based training uses games to build and enhance specific skills, increasing their real-world applicability while engaging participants, boosting cognitive function, and fostering positive mental health outcomes (Choi et al. 2025; Tan et al. 2023; Wang et al. 2021). Exergames, or game-based exercises, combine gaming with physical activity, enhancing engagement while encouraging movement, positively impacting mental health (Huang et al. 2022; López-Nava et al. 2022; Phirom et al. 2020; Xu et al. 2021). Lastly, video games are playful activities within a ludic reality that have become a key aspect of global digital leisure (Adams 2014; Coelho and Abreu 2025c; Muriel and Crawford 2018), which have been applied as intervention tools that engage participants in therapeutic experiences to improve physical and cognitive functions while potentially enhancing mental health (Moller et al. 2023; Suárez-Iglesias et al. 2021).

Given the wide variety of XR and GBI with potential applications in mental health, it was essential to assess which mental health issues are currently concerning society and could be effectively addressed through these approaches. The fast-paced nature of modern life has contributed to rising mental health concerns, including anxiety, depression, and stress (Katiyar et al. 2023; Mendonça et al. 2022; Priya et al. 2020; Salari et al. 2020). Among mental health issues, anxiety, depression, and stress have been extensively studied due to their rising prevalence and growing societal concern, highlighting the need for greater attention from healthcare professionals and policymakers toward their prevention and management (Have et al. 2023; Jalali et al. 2024; Turna et al. 2021). A global study during COVID-19 reported high prevalence rates of these mental health issues, with 50.9% of participants experiencing anxiety, 58.6% depression, and 57.4% stress, highlighting their widespread impact (Shah et al. 2021). These three mental health conditions are deeply interconnected and can severely impact physical health, posing significant risks to both individual quality of life and broader public health (Cohen et al. 2015). Indeed, a study showed that, alongside the urgent need to screen, monitor, and implement interventions for these growing mental health concerns, anxiety, depression, and stress are strongly and positively correlated, potentially amplifying their risks and harms to the population (Al-Garni et al. 2025). With that in mind, XR and GBI have been increasingly explored as potential treatments for anxiety, depression, and stress, offering a promising avenue to address the growing mental health challenges associated with these three conditions (Amer et al. 2024; Lee et al. 2023).

Anxiety, among the most prevalent and chronic mental health conditions, often emerges early in life and significantly impacts well-being and quality of life as its global prevalence continues to rise (Javaid et al. 2023). According to the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) (American Psychiatric Association, 2013), anxiety disorders encompass conditions characterized by heightened fear, anxiety, and related behavioral disruptions, where fear reflects an emotional reaction to an actual or perceived immediate danger, while anxiety involves the anticipation of a potential future threat. Anxiety involves heightened tension, worry, and apprehension (Saviola et al. 2020).

Depressive disorders, according to DSM-5 (American Psychiatric Association, 2013), encompass various conditions, including major depressive disorder—the most common form—characterized by episodes lasting at least two weeks that involve marked changes in mood, cognition, and physiological functions, being recurrent and distinguished from normal sadness or grief by its greater severity, functional impairment, and potential need for clinical treatment.

Depression is characterized by persistent sadness, cognitive impairments, fatigue, and sleep disturbances (Yu et al. 2023). Depression is increasing worldwide, worsening quality of life and mortality rates, and poses a growing global burden that demands deeper analysis and more effective treatment across populations (Moreno-Agostino et al. 2021).

Finally, DS5-5 defines stress-related disorders as mental health conditions triggered by exposure to traumatic or stressful events, encompassing varied symptoms such as anxiety, dysphoria, anger, aggression, or dissociation, and including diagnoses like posttraumatic stress disorder, acute stress disorder, adjustment disorders, and disorders linked to early social neglect (American Psychiatric Association, 2013). Stress disrupts homeostasis through internal or external stressors, triggering regulatory responses for physiological balance (Agorastos and Chrousos 2022). Stress is a major public health concern due to its strong links to physical and mental disorders, economic strain, and social challenges, with chronic stress contributing to diseases like cancer, obesity, cardiovascular conditions, immune dysfunction, and widespread declines in well-being (Smith and Wesselbaum 2025).

Thus, given the rising prevalence and growing concern over anxiety, depression, and stress (Katiyar et al. 2023; Mendonça et al. 2022; Priya et al. 2020; Salari et al. 2020), along with the potential of XR and GBI to improve mental health treatments related to them (Amer et al. 2024; Lee et al. 2023), this umbrella review explores the effects of XR and GBI on anxiety, depression, and stress in the general population. Umbrella reviews assess existing systematic reviews and meta-analyses, ensuring consistency and integrating findings for clearer conclusions (G. J. Choi and Kang 2022). Umbrella reviews are valuable when multiple systematic reviews and meta-analyses exist on a topic (Belbasis et al. 2022), as identified in our database search. Therefore, this study provides a comprehensive synthesis of research on XR, GBI, and mental health, offering high-quality insights through an umbrella review approach.

To assess the combined impact of XR and GBI on anxiety, depression, and stress, we conducted an umbrella review using the PICO framework (Participants, Interventions, Comparisons, Outcomes) to refine search terms and keywords (Pati and Lorusso 2018). Our primary research question was:

- What is the impact of XR-GBI (Interventions), compared to other group conditions (Comparisons), on the general population (Participants), on anxiety, depression, and stress (Outcomes)?

It is important to clarify that "other group conditions", the comparison variable, refers to the types of intervention and control groups reported in the reports included in this umbrella review (i.e., waiting lists, usual treatments, alternative active interventions, or no intervention), as will be further detailed throughout the manuscript. Additionally, we explored two secondary objectives related to the literature:

- What is the risk of bias in the analyzed reports?
- What are the types and characteristics of XR-GBI used?

2 Methods

This umbrella review followed PRISMA guidelines (Page et al. 2021) and was registered in PROSPERO (CRD42025639295). A PROSPERO database search (January 2025) confirmed no similar protocols existed before initiation.

2.1 Eligibility criteria

This umbrella review included systematic reviews, meta-analyses, and scoping reviews meeting the inclusion and exclusion criteria. While umbrella reviews can exclude scoping reviews (G. J. Choi and Kang 2022), we incorporated them as they systematically map evidence and serve as precursors to systematic reviews, addressing broader research questions (Pollock et al. 2024). Also, to ensure high-quality research, we focused only on the randomized controlled trials (RCT) within the reviews, the gold standard for experimental research, as randomization reduces bias and strengthens causal inferences (Hariton and Locascio 2018). It should be noted that, although this umbrella review considered only RCT, the main emphasis of this review is on synthesizing evidence from the systematic reviews, meta-analyses, and scoping reviews that contemplated the RCT. The inclusion criteria were structured using PICO and the research question, as outlined in Table 1.

Concerning the exclusion criteria, we contemplated the topics illustrated in Table 2.

2.2 Information sources and search strategy

The systematic search strategy was devised in collaboration with skilled librarians from our local University and was carried out in January 2025 in the following databases: Scopus, Web of Science, EBSCOHost, ERIC, PubMed, APA, and ACM Digital Library. Our query was elaborated following our main research question, the inclusion and exclusion criteria, and was restricted to systematic reviews, meta-analyses, and scoping reviews. Therefore, we used the following query: ("serious game" OR "game-based" OR gamification OR game OR exergame) AND (anxiety OR depression OR

Table 1 Inclusion criteria

Inclusion criteria	Description
Participants	Studies concerning the general population of any age without any other health comorbidities beyond anxiety, depression, or stress. Due to the possible correlations between anxiety, depression, and stress (Al-Garni et al. 2025), the included studies considered participants presenting one or more of these conditions
Intervention	Only studies that used XR-GBI
Control	The control groups had received an alternative intervention (such as waiting lists, usual treatments, or other active treatments) or no intervention
Outcomes	Only studies related to anxiety, depression, or stress

Table 2 Exclusion criteria

Exclusion criteria	Description
Study category	To contemplate data from studies with scientific rigor and quality, we did not consider studies that were not peer-reviewed, i.e., books, Master's and Ph.D. dissertations, protocols, and workshops
Research type	We considered systematic reviews, meta-analyses, and scoping reviews that analyzed randomized controlled trials. Studies with other types of research design were not considered in this umbrella review. Therefore, certain systematic reviews, meta-analyses, and scoping reviews were only partially considered, focusing solely on the analysis of randomized controlled trials within them, thereby ensuring higher research quality, minimizing bias through randomization, and strengthening causal inferences (Hariton and Locascio 2018)
Language	Studies that were not English-language, as the authors are proficient in this language, and because most indexed scientific articles are available in English, which is the primary language of high-impact journals and ensures broader accessibility to the scientific community (Di Bitetti and Ferreras 2017)

stress) AND ("virtual reality" OR "augmented reality" OR "mixed reality" OR "extended reality") AND ("systematic review" OR "scoping review" OR meta). All primary searches were conducted by attending to the query in the title and abstract.

2.3 Selection process

The study selection process began with database searches conducted with the assistance of the local University librarians. Retrieved records were managed using Zotero and then imported into Rayyan for screening (Ouzzani et al. 2016). The first and second authors reviewed titles and abstracts, removing duplicates and applying inclusion/exclusion criteria. Any uncertainties were resolved together. Disagreements from both authors were resolved with support from the University's librarians.

2.4 Data collection process and items

The first and second authors created and fulfilled an extraction sheet to systematize and analyze data from all included reports. Subsequently, an in-depth analysis was conducted for each selected paper to extract the following information: (1) title; (2) authors; (3) research domain; (4) methods (study type); (5) population; (6) intervention characteristics; (7) conclusions; (8) general report details, and (9) other relevant information.

2.5 Reporting aims and synthesis methods

This umbrella review addresses three key research questions, with Sect. 3 (Results) organized accordingly. First, to address the secondary objective on bias assessment ("What is the risk of bias in the analyzed reports?"), we present the data selection process and categorize reports by risk of bias. Second, to respond to the secondary objective on intervention design ("What are the types and characteristics of XR-GBI used?"), we detail the XR-GBI types and their features. Finally, to answer the main research question ("What is the impact of XR-GBI, compared to non-XR-GBI, on anxiety, depression, and stress in the general population?"), we evaluate XR-GBI's effects on these outcomes, focusing exclusively on RCT.

2.6 Risk of bias assessment

The risk of bias assessment followed AMSTAR 2 guidelines, designed for umbrella reviews (Shea et al. 2017). This tool evaluates 16 questions, determining confidence levels from high (comprehensive summary) to critically low (multiple flaws undermining reliability), with moderate and low intermediate levels. Of these, seven critical questions strongly influence classification, with Table 3 outlining all 16 questions and emphasizing the seven critical ones. Both authors independently assessed all reports, with a third collaborator resolving discrepancies when needed. Reports meeting the inclusion criteria underwent a thorough risk of bias assessment using AMSTAR 2, ensuring rigor, transparency, and reliability.

Table 3 AMSTAR 2

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Overall
Li et al. (2014)	−	−	+	−	−	−	−	+	+	−	+	−	+	+	+	+	Critically low
Drazich et al. (2020)	+	−	+	+	+	+	−	+	+	−	NA	NA	+	+	NA	+	Critically low
Alneyadi et al. (2021)	+	−	+	+	−	−	−	+	−	−	NA	NA	−	+	NA	+	Critically low
Caponnetto et al. (2021)	+	−	+	+	−	−	−	+	+	−	NA	NA	+	+	NA	+	Critically low
Sajeev et al. (2021)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Yen and Chiu (2021)	+	−	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Critically low
Kim et al. (2022)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Pusey et al. (2022)	+	−	+	+	−	−	−	+	−	−	NA	NA	−	+	NA	+	Critically low
Reynard et al. (2022)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Suleiman-Martos et al. (2022)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Bakır et al. (2023)	−	−	+	+	+	+	−	+	+	−	NA	NA	+	+	NA	+	Critically low
Burkhart et al. (2023)	+	+	+	+	+	+	−	+	+	−	NA	NA	+	+	NA	+	Low
Jingili et al. (2023)	+	−	+	+	+	+	−	+	+	−	NA	NA	+	+	NA	+	Critically low
Peng et al. (2024)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Wang et al. (2024)	+	+	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Low
Kulakaç and Ustuner Top (2025)	+	−	+	+	+	+	−	+	+	−	+	+	+	+	+	+	Critically low

Questions: (1) Did the research questions and inclusion criteria for the review include the components of PICO?; (2) Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review, and did the report justify any significant deviations from the protocol? (Critical Question); (3) Did the review authors explain their selection of the study designs for inclusion in the review?; (4) Did the review authors use a comprehensive literature search strategy? (Critical Question); (5) Did the review authors perform study selection in duplicate?; (6) Did the review authors perform data extraction in duplicate?; (7) Did the review authors provide a list of excluded studies and justify the exclusions? (Critical Question); (8) Did the review authors describe the included studies in adequate detail?; (9) Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review? (Critical Question); (10) Did the review authors report on the sources of funding for the studies included in the review?; 11. If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results? (Critical Question); 12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?; 13. Did the review authors account for RoB in primary studies when interpreting/discussing the results of the review? (Critical Question); 14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?; 15. If they performed quantitative synthesis, did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review? (Critical Question); 16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

NA = Not Applicable

Questions 2, 4, 7, 9, 11, 13, and 15 = Critical Questions

3 Results

3.1 Report characteristics

3.1.1 Selection data

A total of 201 records were obtained from the databases. We eliminated 111 duplicate records and screened 90 titles and abstracts, according to the inclusion and exclusion criteria. Then, 38 reports were considered for retrieval, from which 16 were included in this umbrella review after a full-text analysis. Appendix A provides Rayyan tool data, outlining excluded and included records, while Appendix B details the list of included reports, considering their funding and disclosure information—both available online in the Open Science Framework (OSF) project (Open Science Framework 2026). The PRISMA flow diagram representing this process is illustrated in Fig. 1.

Considering the 16 reports, nine were meta-analyses (56%), six were systematic reviews (38%), and one was a scoping review (6%). Seven reports (44%) received funding; however, none reported competing financial interests or conflicts of interest. In terms of publication dates, 15 reports were published from 2020 onward, with only one report dating back to 2014. Figure 2 illustrates the distribution of report publication dates.

A total of 347 articles were considered across 16 reports, with only 80 specifically examining XR-GBI for anxiety, depression, and stress, while the rest focused on other psychological aspects or evaluated XR and GBI separately. Among these 80 articles, 59 were RCT, but only 49 met the inclusion criteria—excluding two without a control group and eight involving other health comorbidities. After removing nine duplicates, 40 unique RCT were included in this umbrella review. Figure 3 illustrates this process, and Appendix C lists all considered RCT, including multiple entries when the same RCT was cited across more than one meta-analysis, systematic review, or scoping review – available online in the OSF project (Open Science Framework, 2026). It is important to note that although this umbrella

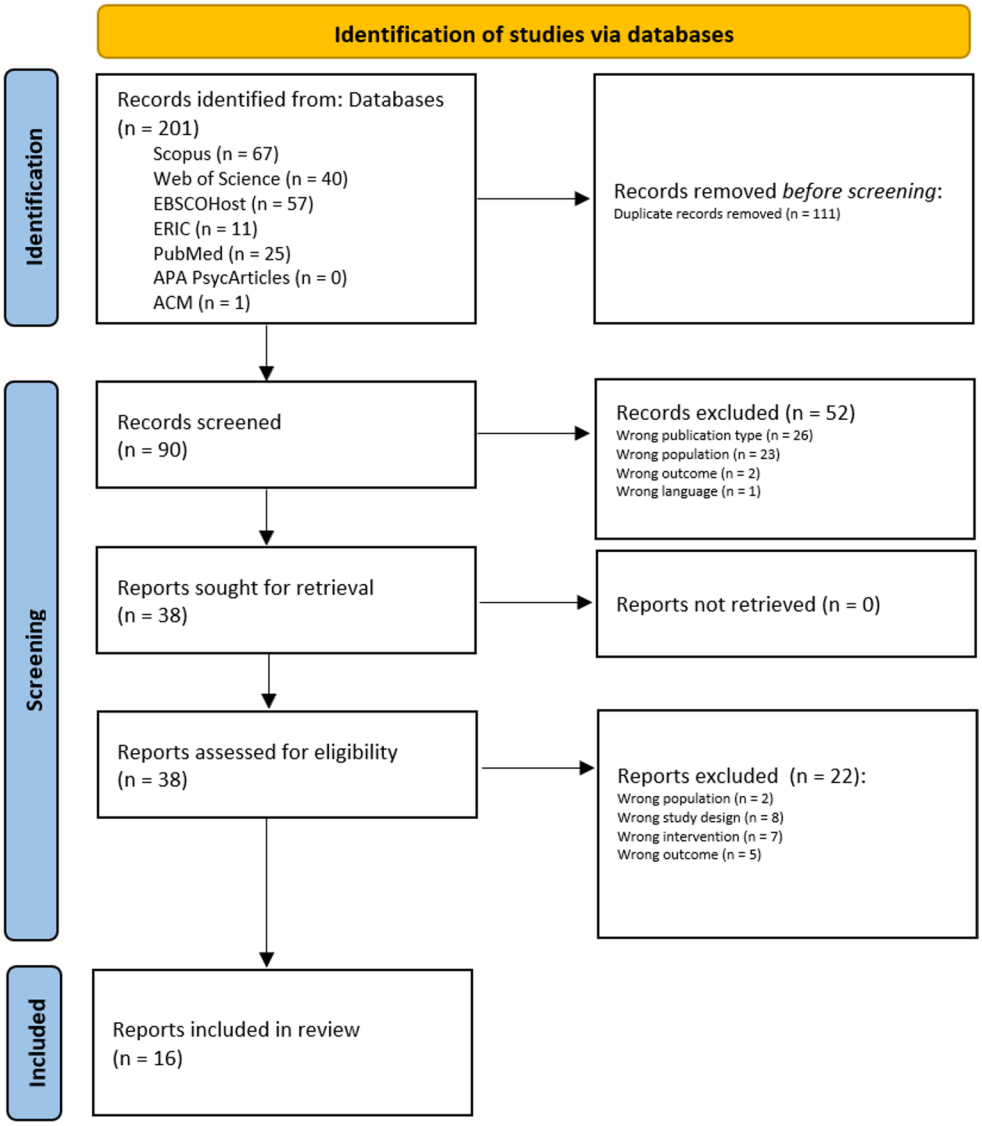

Fig. 1 Prisma flow diagram

review considered only 40 unique RCT, these data are provided solely for descriptive purposes to outline the research landscape, as this review's primary focus is on analyzing the 16 included reports and their assessment of these 40 RCT.

3.1.2 Risk of bias assessment

Using AMSTAR 2 guidelines (Shea et al. 2017), seven reports (44%) were classified as low confidence, and nine (56%) as critically low, with none meeting moderate or high confidence levels due to at least one critical flaw. Three key issues lowered confidence: (1) no report provided an excluded studies list (question 7 – critical); (2) nine lacked a pre-established review protocol (question 2 – critical); and (3) none disclosed funding sources (question 10 – non-critical). Table 3 highlights critical flaw questions and overall confidence ratings.

3.2 Technological features

3.2.1 Extended Realities

VR dominates mental health interventions, appearing in 15 reports (94%), while AR was used in three (19%), with no reports incorporating MR. Regarding hardware, 13 reports (81%) used HMD, seven (44%) utilized mobile phones (standalone or with VR headsets), and three (19%) employed video projectors or screens. All HMD reports included motion tracking. XR served seven purposes, with Virtual Reality Exposure Therapy (VRET) most common (10 reports, 63%), followed by environments for relaxation (five reports, 31%) and fitness training and regular play for fun (four reports, 25%). Figure 4 and Table 4 present all XR application purposes.

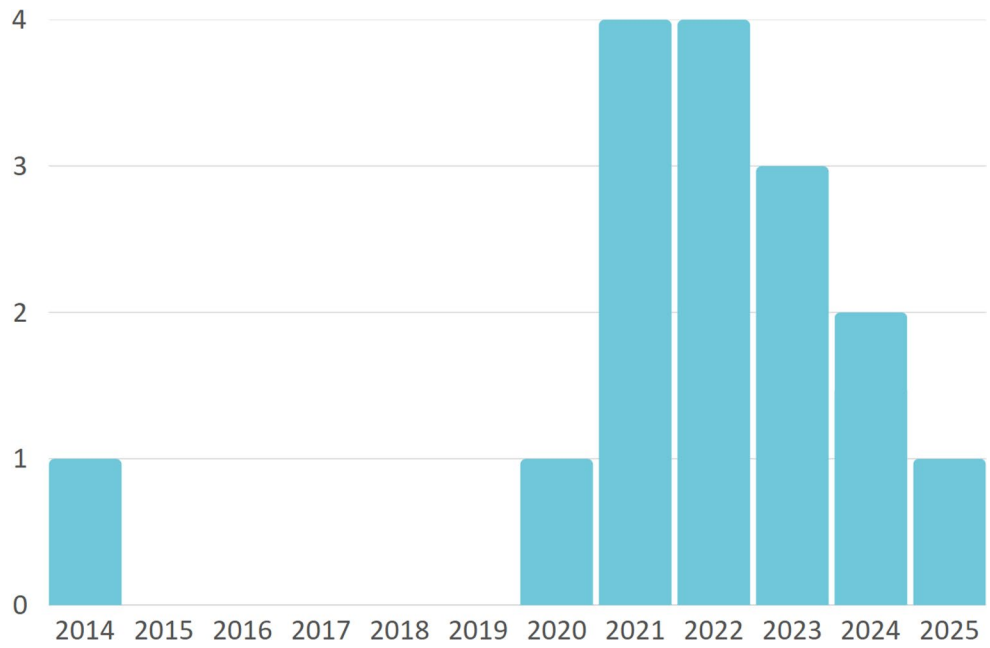

Fig. 2 Report publication dates

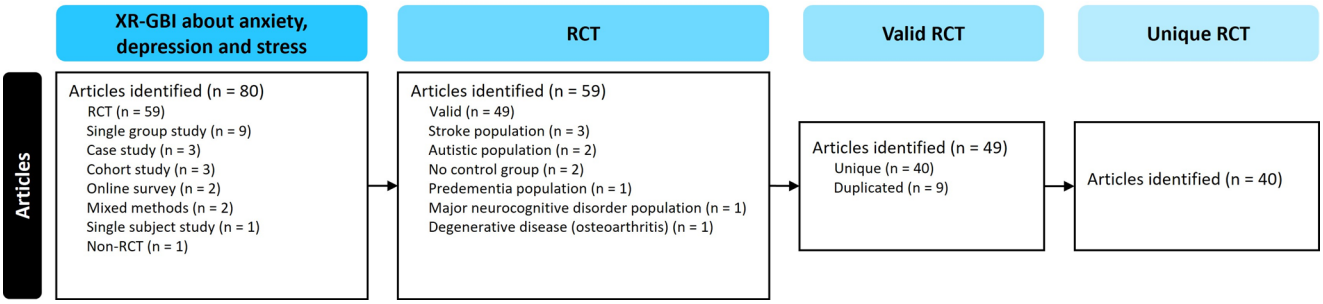

Fig. 3 RCT flow diagram

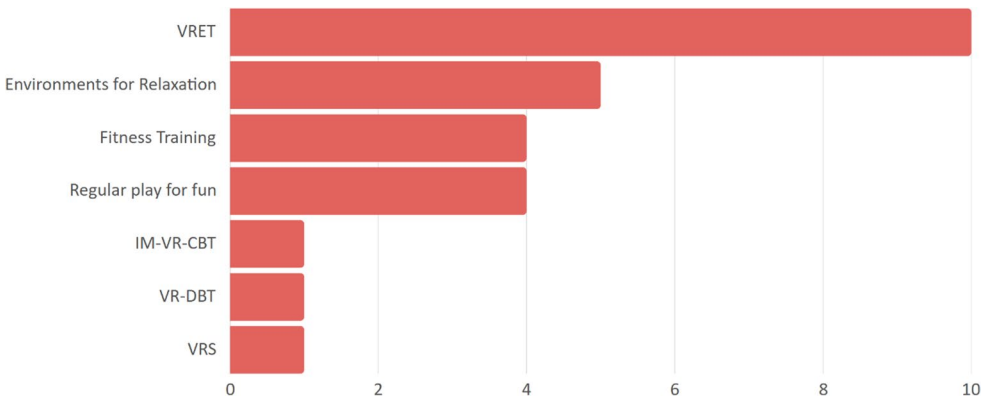

Fig. 4 XR purposes. *Note*. *VRET* Virtual Reality Exposure Therapy, *IM-VR-CBT* Integrative and Multimodal Cognitive Behavioral Therapy Augmented with Virtual Reality; *VR-DBT* Virtual Reality-based Dialectical Behavioral Therapy, *VRS* Virtual Reality-based Self-training

3.2.2 Game-based interventions

Serious games dominated GBI, appearing in 10 reports (63%), followed by commercial video games (seven reports, 44%), exergames (four reports, 25%), and gamification (three reports, 19%) (Fig. 5). No reports included game-based learning or training. Regarding software, 11 reports (69%) used commercially available GBI, while 10 (63%) employed custom-developed GBI from research labs or industry partners. Referenced commercial GBI include Amazon Program GAMotion, NeuroVR 2, Nintendo Switch games, Nintendo Wii Fit games (Step and Nodding), Ocean Rift (Picselica), Pebbles the Penguin and Space Pups (Mighty Immersion), Pokémon GO, Snowthrow VR, Virtual Iraq/Afghanistan VR, and Xbox Kinect games (Kinect

Table 4 XR purposes description

Purposes	Description	Reports
Virtual reality exposure therapy (VRET)	A type of Virtual Reality-based Cognitive Behavioral Therapy (VR-CBT), with computer-generated virtual environments that replicate real-life situations, offering individuals a controlled and secure space to face and address circumstances	Li et al. (2014), Alneyadi et al. (2021), Caponnetto et al. (2021), Sajeev et al. (2021), Kim et al. (2022), Pusey et al. (2022), Suleiman-Martos et al. (2022), Jingili et al. (2023), Wang et al. (2024), Kulakaç and Ustuner Top (2025)
Environments for relaxation	The integration of virtual environments featuring visual and auditory stimuli designed to induce relaxation, including serene landscapes and calming activities like watering plants	Sajeev et al. (2021), Suleiman-Martos et al. (2022), Jingili et al. (2023), Wang et al. (2024), Kulakaç and Ustuner Top (2025)
Fitness training	The combination of virtual reality and physical exercise, engaging users in immersive environments that encourage body movement and active participation	Drazich et al. (2020), Yen and Chiu (2021), Kim et al. (2022), Peng et al. (2024)
Regular play for fun	The utilization of games primarily for entertainment, while simultaneously conducting assessments, such as engaging with a standard commercial video game	Sajeev et al. (2021), Reynard et al. (2022), Bakır et al. (2023), Burkhart et al. (2023)
Integrative and multimodal cognitive behavioral therapy augmented with VR (IM-VR-CBT)	A type of Virtual Reality-based Cognitive Behavioral Therapy (VR-CBT), with a personalized psychotherapeutic approach that combines classical and modern cognitive-behavioral techniques, focusing on modifying irrational beliefs, regulating emotions, and addressing underlying dysfunctional processes in psychopathology	Jingili et al. (2023)
Virtual reality-based dialectical behavioral therapy (VR-DBT)	A type of Virtual Reality-based Cognitive Behavioral Therapy (VR-CBT), with a virtual-reality therapeutic approach designed to improve attentional control and emotional regulation, focusing on mindfulness for individuals with attention deficits and emotional dysregulation	Jingili et al. (2023)
Virtual reality-based self-training (VRS)	A type of Virtual Reality-based Cognitive Behavioral Therapy (VR-CBT) that serves as a platform for developing social skills by simulating environments where individuals can practice and enhance social interactions	Jingili et al. (2023)

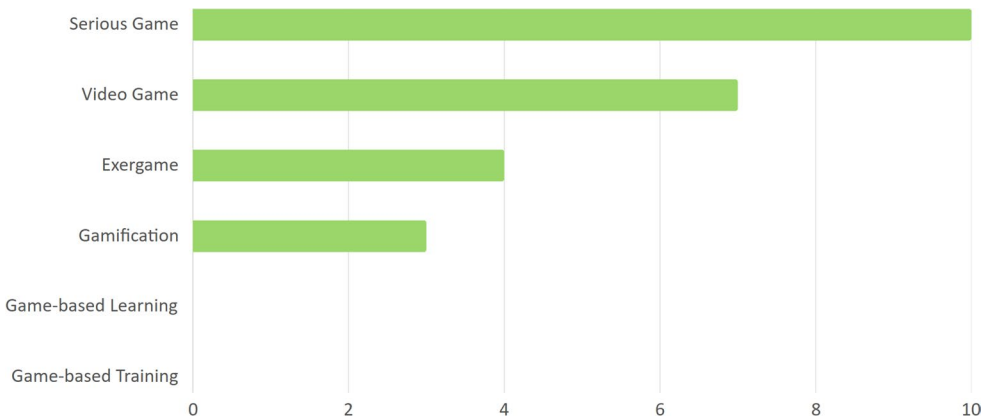

Fig. 5 GBI

Sports Ultimate Collection, Your Shape Fitness Evolved, Dance Central, Nike + Kinect Training).

3.3 Mental health impact

Among all reports, nine (56%) analyzed XR-GBI for anxiety treatment, followed by seven (44%) for depression, and five (31%) for stress. Figure 6 represents these proportions, and Table 5 presents the mental health conditions addressed in the reports, related to anxiety, depression, and stress.

Each of these mental health conditions was further examined based on the target population and the specific intervention applied. Table 6 illustrates the relationship between reports, mental health conditions, and population. For Table 6 and subsequent analyses in this paper, the population was categorized into three groups: children and adolescents (< 18 years), adults (18–60 years), and older adults (≥ 60 years).

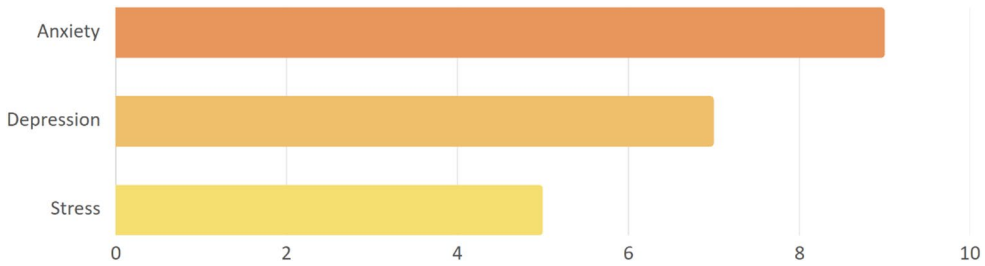

Fig. 6 Mental health impact

Table 5 Mental health conditions

Mental health	Assessed conditions
Anxiety	Preoperative/procedural anxiety and emergence delirium
	Social anxiety disorder (SAD)
	Phobia (acrophobia)
	Generalized anxiety disorder (GAD) and general anxiety traits
	Public speaking anxiety (PSA)
	Panic disorder
	Fear of negative evaluation (FNE)
Depression	General depressive symptoms
	PTSD-related depression
Stress	Indirect stress-related outcomes (cognition, emotional regulation)
	PTSD-related stress
	Perceived stress

3.3.1 Anxiety

3.3.1.1 Children and adolescents This dataset includes six reports examining anxiety management in children and adolescents (< 18 years). Five reports focused on preoperative, procedural anxiety, and emergence delirium (Burkhart et al. 2023; Kulakaç and Ustuner Top 2025; Sajeev et al. 2021; Suleiman-Martos et al. 2022; Wang et al. 2024), and one reported social anxiety disorder (SAD) (Jingili et al. 2023). Intervention types varied, including VRET, VRS, regular play for fun, and relaxation environments. All reports employed questionnaires or scales for assessment, with one incorporating observational methods (Sajeev et al. 2021) and one using observational methods and parental evaluation (Jingili et al. 2023). Regarding neurophysiological and physical assessments, just one report reported the use of eye-tracking for gaze-based interaction (Sajeev et al. 2021). Five reported head and body motion detectors (Burkhart et al. 2023; Kulakaç and Ustuner Top 2025; Sajeev et al. 2021; Suleiman-Martos et al., 2022; Wang et al. 2024). All interventions were individual-based with single sessions, except for one report that reported only group-based therapy for SAD with multi-week programs with 24 sessions (Jingili et al. 2023).

Of the six reports, five demonstrated significant anxiety reduction in preoperative, procedural, and postoperative cases, with some reports showing equal performance, compared to a waitlist group, no intervention, or usual treatments—such as standard of care, regular instruction, watching TV or other distraction program (Burkhart et al.

Table 6 Mental health and population

Reports	Anxiety			Depression			Stress		
Age	< 18	18–60	≥ 60	< 18	18–60	≥ 60	< 18	18–60	≥ 60
Li et al. (2014)		✓			✓			✓	
Drazich et al. (2020)						✓			
Alneyadi et al. (2021)		✓							
Caponnetto et al. (2021)		✓							
Sajeev et al. (2021)	✓								
Yen and Chiu (2021)						✓			
Kim et al. (2022)						✓			
Pusey et al. (2022)					✓			✓	
Reynard et al. (2022)							✓		
Suleiman-Martos et al. (2022)	✓								
Bakır et al. (2023)							✓		
Burkhart et al. (2023)	✓								
Jingili et al. (2023)	✓	✓			✓			✓	
Peng et al. (2024)						✓			
Wang et al. (2024)	✓								
Kulakaç and Ustuner Top (2025)	✓								
Total	6	4	0	0	3	4	2	3	0

2023; Kulakaç and Ustuner Top 2025; Sajeev et al. 2021; Suleiman-Martos et al. 2022; Wang et al. 2024). One report reported a significant reduction in SAD diagnosis following treatment, demonstrating comparable effectiveness in reducing anxiety to usual treatments such as CBT – specifically the Social Effectiveness Therapy for Children (SET-C) (Jingili et al. 2023). Therefore, in children and adolescents, interventions mainly addressed preoperative and procedural anxiety, with single sessions proving effective, as XR-GBI served as a distraction and relaxation tool to alleviate anxiety, fear, and pain during medical procedures.

3.3.1.2 Adults This dataset includes four reports implicated in treating anxiety among adults (>18<60 years old). The reports focused on a diverse set of mental health conditions: one included acrophobia (i.e., intense anxiety and fear related to heights) (Li et al. 2014), two considered social anxiety disorder (SAD) (Caponnetto et al. 2021; Jingili et al. 2023), two analysed public speaking anxiety (PSA) (Caponnetto et al. 2021; Jingili et al. 2023), one included generalized anxiety disorder (GAD) and general anxiety traits (Alneyadi et al. 2021), and one discussed also other conditions such as panic disorder, fear of negative evaluation (FNE) and Social anxiety disorder (SAD) (Jingili et al. 2023). A variety of treatment approaches were applied, including VRET, VR-DBT, IM-VR-CBT, VRS, and environments for relaxation.

All reports used questionnaires and self-reported scales to assess the effectiveness of interventions. Only two reports (Alneyadi et al. 2021; Jingili et al. 2023) reported advanced neurophysiological and physical assessments, such as cardiovascular belts and heart rate monitors to assess cardiac activity, wrist and finger sensors to measure movement, stress, temperature, and electrodermal activity, biosensors for respiratory patterns, Electroencephalogram (EEG) and Electromyography (EMG) for neural and muscular responses, and eye-tracking and voice detectors for analyzing gaze behavior and vocal responses. The four reports referenced head and body motion detectors. All reports showed individual intervention settings, with one report also analysing the integration of group-based therapy sessions (Jingili et al. 2023). The frequency of interventions varied, ranging from single-session protocols to multi-week structured programs extending up to 12 sessions.

All reports demonstrated significant reductions in symptoms of anxiety following XR-GBI in adults. One meta-analysis found that VR interventions were effective in treating phobias through exposure therapy, equally comparable to usual treatments—such as CBT (Li et al. 2014). Another report reported that regular VR and combining VR with biofeedback significantly enhanced anxiety reduction and emotional skills as a coping strategy, outperforming traditional CBT and waitlist conditions (Alneyadi et al. 2021). Two reports investigating public speaking anxiety (PSA) found that VR was more effective than waitlist or no intervention control and as effective as traditional CBT, but with lower dropout rates, suggesting higher engagement and treatment adherence for XR-based therapy, together with lower costs and higher flexibility for achieving greater psychophysical well-being (Caponnetto et al. 2021; Jingili et al. 2023). Finally, another report reported a significant decrease in anxiety symptoms related to panic disorder, FNE, and SAD, compared to waitlist groups and no intervention, showing similar effectiveness of CBT (Jingili et al. 2023). Therefore, for adults, XR-GBI interventions primarily targeted various anxiety disorders and proved to be an effective approach for delivering VR-based exposure therapy and CBT.

Table 7 presents the effects of XR-GBI on various aspects of anxiety in children, adolescents, and adults, summarizing whether the results related to that mental health aspect were significantly positive, equal to, or negative in improving symptoms compared to the respective control groups described in the included reports.

3.3.2 Depression

3.3.2.1 Adults This dataset includes three reports investigating depression in adults (>18<60 years old), exploring the general aspects of depression (Jingili et al. 2023; Li et al. 2014; Pusey et al. 2022). The reports applied VRET as a core intervention, with one report (Jingili et al. 2023) also incorporating VR-DBT, IM-VR-CBT, VRS, and environments for relaxation.

All reports employed self-reported questionnaires and clinical scales to assess depression-related symptoms. Concerning neurophysiological and physical assessments, just one report (Jingili et al. 2023) reported the use of EEG and EMG to capture objective measures of emotional, cognitive, and muscular responses. All reports reported head and body motion detectors. The interventions were primarily individual-based, though one report (Jingili et al. 2023) included group-based therapy. Intervention duration ranged from single-session protocols to structured multi-week programs lasting up to 12 sessions.

Among the three reports, one reported a significant reduction in general depressive symptoms following XR-GBI interventions (Jingili et al. 2023), compared to the waitlist group, no intervention, or standard therapeutic program. The other two reports (Li et al. 2014; Pusey et al. 2022) analysed depressive symptoms in PTSD-related populations and demonstrated that XR-GBI was as effective as standard CBT (specifically, Traditional Prolonged Exposure Therapy or Exposure in Imagination) in the short and long-term treatment of depression, showing significant symptom

Table 7 XR-GBI for anxiety treatments

Reports	Population	Anxiety condition	Impact (vs. Control)	Control
Burkhart et al. (2023), Kulakaç and Ustuner Top (2025), Sajeev et al. (2021), Suleiman-Martos et al. (2022), Wang et al. (2024)	Children and adolescents	Preoperative/procedural anxiety and emergence delirium	Equal and positive	Waiting list; no intervention; standard care; regular instruction; non-VR distraction (e.g., TV)
Jingili et al. (2023)	Children and adolescents	Social anxiety disorder (SAD)	Equal	Usual treatments, such as CBT and Social Effectiveness Therapy for Children (SET-C)
Li et al. (2014)	Adults	Phobia (acrophobia)	Equal	Usual treatments, such as CBT
Alneyadi et al. (2021)	Adults	Generalized anxiety disorder (GAD) and general anxiety traits	Positive	Waitlist; no intervention; usual treatments, such as CBT
Jingili et al. (2023), Caponnetto et al. (2021)	Adults	Public speaking anxiety (PSA)	Equal and positive	Waitlist; no intervention; usual treatments, such as CBT
Jingili et al. (2023)	Adults	Panic disorder, fear of negative evaluation (FNE), social anxiety disorder (SAD)	Equal and positive	Waitlist; no intervention; usual treatments, such as CBT

Table 8 XR-GBI for depression treatments

Reports	Population	Depression condition	Impact (vs. Control)	Control
Jingili et al. (2023)	Adults	General depressive symptoms	Positive	Waitlist; no intervention; standard therapeutic program
Pusey et al. (2022), Li et al. (2014)	Adults	PTSD-related depression	Equal and positive	Waitlist; usual treatments, such as CBT
Peng et al. (2024), Yen and Chiu (2021), Kim et al. (2022), Drazich et al. (2020)	Older adults	General depressive symptoms	Equal and positive	Waitlist; no intervention; active control group with exercises; standard care

improvement compared to the waitlist control group. For adults, XR-GBI focused on depression demonstrated effectiveness in delivering various therapies, particularly VR-based exposure therapy, as with anxiety treatment, showing some similarities.

3.3.2.2 Older adults This dataset includes four reports investigating depression in older adults (≥60 years old), also exploring the general aspects of depression (Drazich et al. 2020; Kim et al. 2022; Peng et al. 2024; Yen and Chiu 2021). All reports reported the use of XR-GBI for fitness training, with one report also including VRET (Kim et al. 2022).

All reports utilized questionnaires and self-reported clinical scales to evaluate depression symptoms. No reports reported a neurophysiological assessment. All reports integrated physical tracking via head and body motion detectors, and one report incorporated balance monitoring using a balance board (Drazich et al. 2020). All reports were conducted in individual therapy settings, and intervention durations ranged from 3 to 13 weeks.

Among the four reports, two reported significant reductions in depression symptoms following XR-GBI interventions (Peng et al. 2024; Yen and Chiu 2021), with some articles reporting equal performance when compared to various control conditions, such as waitlist groups, no intervention, active control groups, or standard care, like physical and occupational therapy, and physiotherapy. Furthermore, it is important to highlight that one of those reports (Peng et al. 2024) indicated that commercial VR game systems were more effective than self-developed systems in reducing depressive symptoms, although both demonstrated a positive impact. The two other reports (Drazich et al. 2020; Kim et al. 2022) reported no significant impact on depression outcomes, despite improvements in fear of falling, balance, and fall risk reduction. Thus, in older adults, XR-GBI was predominantly used in the form of exergames, indicating a strong link between physical exercise and depression treatment for this group.

Table 8 summarizes the effects of XR-GBI on various aspects of depression in adults and older adults, presenting whether the results related to that mental health aspect were statistically significantly positive, equal to, or negative in improving symptoms compared to the respective control groups described in the included reports.

3.3.3 Stress

3.3.3.1 Children and adolescents This dataset includes two reports investigating stress in children and adolescents (<18

years old). Both reports examined the indirect effects on mental well-being through cognition and emotional regulation using an AR mobile video game, but did not address stress directly (Bakır et al. 2023; Reynard et al. 2022). The reports employed self-reported or clinical questionnaires and scales to measure cognitive and emotional outcomes. No neurophysiological or physical tracking methods were used in these interventions. The reports followed an individual therapy format, with interventions lasting for eight weeks.

The two reports reported enhanced selective attention, cognitive control, physical exercises, and sociability in intervention groups compared to control conditions of no intervention, indicating better emotional intelligence and regulation (Bakır et al. 2023; Reynard et al. 2022), indirectly alleviating emotional stress. Thus, XR-GBI for children and adolescents was the only group relying exclusively on commercial video games, aiming not to directly reduce stress but to address cognitive and emotional factors that could indirectly influence it, though this interpretation is limited by the unclear relationship between these variables.

3.3.3.2 Adults This dataset includes three reports exploring stress in adults (≥18 years old), investigating general aspects of stress and Post-traumatic Stress Disorder (PTSD) (Jingili et al. 2023; Li et al. 2014; Pusey et al. 2022). The treatment approaches varied, with all reports incorporating VRET, while one report (Jingili et al. 2023) also included VR-CBT, VR-DBT, IM-VR-CBT, and VRS.

All reports used self-reported or clinical questionnaires and scales to evaluate stress and PTSD-related symptoms. Only one report (Jingili et al. 2023) incorporated neurophysiological and physical assessments, including eye-tracking, voice detection, biosensors for heart rate, EEG, EMG, and voice biometric analysis. All reports reported motion detection via head and body. The interventions were mostly conducted individually, though one report (Jingili et al. 2023) included group-based therapy. Intervention durations ranged from 3 to 12 sessions.

The three reports demonstrated significant reductions in symptoms related to PTSD following XR-GBI, compared to waitlist control groups or showing comparable efficacy to other treatments, such as CBT. From these three reports, one report (Pusey et al. 2022) on PTSD-related stress in soldiers found VRET as effective as Traditional Prolonged Exposure Therapy in symptom improvement. However, post hoc analysis showed greater PTSD symptom reduction with traditional therapy at three- and six-month follow-ups, indicating potential differences in long-term efficacy. Another report also assessed general perceived stress and reported a significant reduction compared to waitlist or active control groups, while demonstrating comparable effectiveness to other conditions, like usual treatment with CBT (Jingili et al. 2023). XR-GBI for adults targeting stress reduction primarily utilized VRET, and, as with treatments for anxiety and depression, VR-based exposure therapy appears to be an effective approach for alleviating symptoms across all three mental health conditions—anxiety, depression, and stress.

Table 9 shows the effects of XR-GBI on various aspects of stress in children, adolescents, and adults, summarizing whether the results related to that mental health aspect were statistically significantly positive, equal to, or negative in improving symptoms compared to the respective control groups described in the included reports.

4 Discussion

This umbrella review examines the effects of XR-GBI on anxiety, depression, and stress in the general population by synthesizing findings from 16 reports selected from 201 articles, including nine meta-analyses, six systematic reviews, and one scoping review. The evidence highlights XR-GBI as a promising tool for mental health interventions, despite methodological challenges. We analyze the features of XR-GBI across different age groups, assessing its impact on children, adolescents, adults, and older adults for each mental health condition. This section follows the data analysis structure outlined in Sect. 3 (Results) and concludes by integrating all findings into a unified theoretical model for XR-GBI. The model highlights the potential of these technologies to support mental health treatment and advance research in this field.

Table 9 XR-GBI for stress treatments

Reports	Population	Stress condition	Impact (vs. Control)	Control
Bakır et al. (2023), Reynard et al. (2022)	Children and adolescents	Indirect stress-related outcomes (cognition, emotional regulation)	Positive	No intervention
Jingili et al. (2023), Li et al. (2014) Pusey et al. (2022)	Adults	PTSD-related stress	Equal and positive	Waitlist; usual treatments such as CBT
Jingili et al. (2023)	Adults	Perceived stress	Equal and positive	Waitlist; active control group; usual treatments such as CBT

4.1 Report characteristics

XR-GBI research is still emerging, with 15 of 16 reports published in the last five years and only 40 unique RCT identified. All reports had low or critically low confidence, with no moderate or high ratings. Key bias issues were related to missing excluded studies lists, undefined review protocols, and undisclosed funding sources, aligning with Cochrane guidelines (Higgins et al. 2023), emphasizing the need for more rigorous investigations to improve confidence in XR-GBI findings. According to the Cochrane Collaboration's guidelines, these flaws lead to: (1) a lack of transparency in study selection; (2) bias from undefined protocols; and (3) potential financial conflicts of interest. Also, ensuring RCT external validity is crucial for generalizability and model reliability of systematic reviews (Coelho et al. 2024a; Khorsan and Crawford 2014), yet none of the reports addressed this. The recency of published reports, limited RCT availability, and methodological weaknesses confirm XR-GBI as an emerging research field. Thus, these data are essential for contextualizing the discussions in this section. While XR-GBI shows promise for mental health, methodological limitations in the reports reviewed must be considered when interpreting and generalizing our findings.

4.2 Technological features

4.2.1 Extended realities

VR dominates mental health interventions, while AR remains limited, and MR is absent. HMD-based VR is favoured for VRET and relaxation due to its immersive nature. Traditional CBT exposure therapy requires therapist guidance but faces accessibility barriers like time, insurance, and logistics, whereas VR provides a more accessible, immersive alternative (Krzystanek et al. 2021). In today's fast-paced world, VR serves as a convenient relaxation tool, especially in confined spaces (Li et al. 2021; Riches et al. 2021). Though less effective than real nature, it still offers therapeutic benefits for relaxation, helping reduce heart rate, respiration, and blood pressure while blocking external distractions (Frost et al. 2022; Naef et al. 2022). VR's therapeutic potential relies on interactivity, where users modify virtual environments; presence, the sense of being inside a virtual place; and flow, a deep state of immersion (Badilla-Quintana and Sandoval-Henríquez 2021). It also surpasses traditional screens, enabling 3D spatial interactions (Fang 2024).

Despite VR's dominance, AR remains underutilized, and MR is absent, presenting a research gap. Both could integrate virtual elements into real-world settings, improving cognitive and behavioral training (Usmani et al. 2022). AR in shared physical spaces leverages digital engagement to enhance real-world social connections and foster a sense of belonging (Mittmann et al. 2022). Location-based AR games, like Pokémon GO, promote physical activity, new friendships, and mental well-being (Ku et al. 2021). Similarly, AR apps like Zombies, Run! increase immersion and motivation for physical activity by combining storytelling with exercise, encouraging long-term participation (Farič et al. 2021).

MR enhances social interaction by integrating virtual humans into real environments, enabling lifelike communication for education, companionship, and healthcare (Pimentel and Vinkers 2021). It also amplifies emotional engagement through multisensory simulations, as seen in a refugee migration study, which fostered empathy via shared narratives and immersive experiences with audiovisual, tactile, vestibular, proprioceptive, and olfactory stimuli (Kors et al. 2016). Beyond social aspects, MR reduces cognitive load, improves perception and spatial skills, and enables gesture-based problem-solving with 3D holograms (Gannina et al. 2024; Piri et al. 2024).

Thus, AR and MR are promising tools for further exploration, though several barriers may hinder their development and implementation. Barriers to AR implementation include achieving high-resolution visual interactivity, intuitive interaction with virtual content, and precise user tracking in any environment—especially when relying on HMD instead of smartphones, which also raises the challenge of making such devices socially acceptable (Billinghurst 2021). Location-based AR games and applications pose technical challenges for both designers and players, particularly due to issues like fluctuating GPS accuracy and rapid battery drain of devices (Alha et al. 2023). Beyond infrastructure challenges and production costs, the adoption of AR also relies on the readiness of researchers and professionals to integrate these technologies, but limited training and awareness may hinder effective implementation (Mondal and Mondal 2025).

Concerning MR challenges, the general barriers of technology are expensive hardware and limited resources for training, which amplify complexity in the implementation stage, hindering the full potential of these technologies (Thi Vo 2025). MR in healthcare faces key difficulties such as usability challenges, high hardware costs, limited accessibility, ergonomic concerns, and the need for greater realism and interoperability (Rincon et al. 2023). Although some studies have sought to develop more affordable yet high-quality MR technologies as cost-effective alternatives to expensive MR systems (Hu et al. 2024), this field still seems to be in its early stages of dissemination.

In addition to the existing barriers to AR and MR implementation, this umbrella review underscores the scarcity of

high-quality experimental research (particularly RCT) using these technologies, which hinders the replication of effective protocols and sustains the gap in their practical application and investigation. Therefore, future research should explore AR and MR in mental health, leveraging real-world integration to enhance social, physical, and cognitive development.

4.2.2 Game-based interventions

Serious games dominated GBI, while gamification was the least used (19%), and game-based learning and training were not used. Serious games' prevalence reflects a focus on goal-oriented, fully developed games for therapy, embedding educational objectives into engaging gameplay (Dimitriadou et al. 2021). Serious games provide a cost-effective, structured approach to mental health support, offering accessible interventions for symptom relief (Dewhirst et al. 2022).

Despite its proven impact on engagement and behavior change (Al-Rayes et al. 2022), gamification was underutilized in XR-GBI. Gamification enhances cognition, learning, physical activity, behavioral modification, emotional regulation, and mental health (Coelho et al. 2025a, b; Gkintoni et al. 2024). while also improving treatment effectiveness (Cheng and Ebrahimi 2023). Additionally, all the XR-GBI reports were analyzed for design principles, game elements, and their motivational purposes by using a gamification framework (Klock et al. 2020) and further described in another study (Coelho and Abreu 2025a). According to this study, most XR-GBI incorporated game elements promoting emotional regulation, self-development, behavioral change, and cognitive skill-building, supporting mental health interventions through adaptive learning via exploratory simulations, structured storytelling, and real-time assessment. Also, the study highlights the strong use of game elements linked to intrinsic motivation, while the limited integration of social game elements suggests that multiplayer aspects remain underexplored, emphasizing the need for future research to incorporate cooperative, collaborative, and competitive mechanics into XR-GBI.

Psychoeducation empowers patients, families, and caregivers by providing knowledge about disorders and equipping them with coping strategies, helping individuals recognize their distress as a treatable condition rather than a personal failing, which encourages treatment-seeking, improves adherence by clarifying therapeutic processes and expected outcomes, and ultimately contributes to symptom reduction (Oliveira and Dias 2023). In that context, game-based learning leverages digital games for education by balancing learning and gameplay, while integrating technology into social-emotional programs can boost interest in mental health, positively impacting personal, emotional, and social well-being (Barrera et al. 2021). Finally, many mental disorders involve cognitive deficits, such as depression, which is associated with impairments in memory, attention, and executive function that can persist post-remission; and game-based cognitive training has been designed to address these deficits by effectively enhancing cognitive skills and potentially alleviating depressive symptoms (Lukka and Palva 2023). Therefore, our results call for studies, particularly RCT, on the role of gamification and game-based learning and training in XR therapy, as they might provide different cognitive benefits (Coelho et al. 2025).

4.3 Mental health impact

XR-GBI has consistently reduced anxiety, depression, and stress, with all reports showing positive outcomes over control groups (such as waiting lists, treatment as usual, other active treatments, or no intervention). As digital mental health solutions gain recognition, XR-GBI can improve accessibility for individuals facing barriers to traditional therapy (Lattie et al. 2022). While some HMD-based VR systems remain expensive, ongoing advancements in technology and hardware have gradually reduced costs, helping to overcome some of the initial barriers to adopting this technology in mental health care (Pedram and Piatkowski 2025). Given the long-term impact of mental health issues, particularly in younger populations (Kim et al. 2024), XR-GBI represents an effective, scalable, and cost-effective intervention. Therefore, XR-GBI shows promise for public mental health (Jerdan et al. 2018). Additionally, VR's immersive simulations can aid in detecting anxiety and depression (Martinez et al. 2021). However, despite its effectiveness, the field requires further investigation, as the limited availability of RCT still restricts evidence (Lüddecke and Felnhofer 2022).

A key limitation found is the reliance on subjective measures for diagnosing mental health conditions. Among 16 reports, only three (Alneyadi et al. 2021; Jingili et al. 2023; Sajeev et al. 2021) incorporated neurophysiological tracking (EEG, EMG, heart rate, electrodermal activity, biosensors for respiration, voice detection, eye tracking), mostly in adult reports. Objective data enhances diagnostic and assessment accuracy (Li et al. 2022), aiding in the diagnosis of mental health conditions. Nonetheless, integrating both subjective and objective assessments is crucial, as interoception, for instance (i.e., awareness of bodily states), plays a role in anxiety disorders (Domschke et al. 2010). In VR, place illusion reduces cardiac interoceptive accuracy, as diminished embodiment weakens bodily awareness, underscoring the importance of incorporating physiological data, given that self-reported measures, such as heartbeat

perception, may be less accurate in virtual environments. (El Ali et al. 2023a, b).

Regarding emerging neurophysiological tools with potential for further research and application, one study presented Neuroscreen—a smartphone-based cognitive assessment combined with EEG—offering a cost-effective solution that supports home-based therapy and facilitates more ecologically valid research (Nami et al. 2022). Machine learning further optimizes personalized treatment (Sajno et al. 2023). Additionally, GBI integrates interactive biofeedback, using real-time physiological tracking as both assessment and game input (Coelho et al. 2025). For instance, one study employed a stretchable belt for breath awareness, adjusting game lighting with inhalation and EEG monitoring to modify background music based on focus levels (Lu et al. 2023). Therefore, expanding neurophysiological biofeedback in XR-GBI might enhance engagement and diagnostic reliability.

Our findings also highlight that individual-based interventions dominate XR-GBI mental health applications, with limited research on group-based therapy. While XR-GBI provides replicable, customized solutions without the need for real-time professional supervision (Heyse et al. 2019), social support is crucial for mental health and reducing anxiety, depression, and stress (Acoba 2024). Emerging neurosociology research suggests that the metaverse could transform social interaction studies through hyperscanning and interbrain synchrony, where EEG monitoring in virtual meetings offers insights into group dynamics and decision-making beyond traditional methods (Maslova et al. 2025). Future studies should explore social therapy formats within XR-GBI to enhance emotional well-being.

The overall positive impact of XR-GBI on anxiety, depression, and stress, along with the dominance of subjective assessments and individual interventions, defines most reports in this umbrella review, though findings vary across conditions and populations.

4.3.1 Anxiety

The findings highlight the growing use of XR-based interventions for anxiety, with VRET as the dominant approach. Among children and adolescents, treatments primarily targeted preoperative and procedural anxiety, with single-session interventions effectively reducing symptoms and SAD. XR-GBI functions as a distraction and relaxation tool, easing anxiety, fear, and pain during medical procedures by engaging patients in immersive experiences (Flores et al. 2023; GS et al. 2021). Neurologically, XR-GBI reduces salience network activity while enhancing the default mode network, with the prefrontal cortex (PFC) strengthening its connection, which may help reduce pain and anxiety (Nagamine 2025). Additionally, PFC activation supports high-level coping strategies, modulates autonomic responses via the amygdala, and facilitates signal transmission from the thalamus to the cortex, further alleviating anxiety (Kenwood et al. 2022). VR's immersive effects can be enhanced with eye-tracking for gaze interaction when head movement is restricted. Integrating sensory elements like wind, temperature shifts, vibrations, sound, and touch could create a richer, more engaging therapeutic environment (Al-Ghamdi et al. 2020; Tao and Lopes 2022).

For adults, XR interventions address a broader range of anxiety disorders, including phobias, GAD, PSA, SAD, panic disorder, and FNE. VR-based exposure therapy and CBT were primarily applied to anxiety treatments for adults, with both approaches demonstrating effectiveness comparable to traditional therapies, but with lower dropout rates, suggesting higher engagement and adherence (Caponnetto et al. 2021), making VR a cost-effective, flexible mental health tool. CBT fosters alternative responses to conditioned fear, with emotional processing theory emphasizing habituation, while VR-based exposure therapy offers controlled environments to address safety behaviors and dysfunctional thoughts (Ørskov et al. 2022). Positive CBT outcomes correlate with brain activity in salience and interoception-related regions, including the fronto-insular and fronto-limbic cortices, which regulate emotional processing and self-awareness (Picó-Pérez et al. 2023). VR therapy, based on the brain's emotional network model, gradually reduces fear by introducing non-threatening stimuli, helping patients restructure responses until anxiety diminishes (Wu et al. 2021). Internet-delivered CBT (iCBT) and digital mindfulness-based interventions complement traditional therapy and can be implemented in VR for treating phobias, panic disorder, SAD, and GAD (Apolinário-Hagen et al. 2020).

4.3.2 Depression

The results highlight the widespread use of XR-based interventions for depression, especially among adults and older adults, with VRET and VR Exergames as the primary approaches. For adults, similar to anxiety treatments, XR-GBI effectively reduced depressive symptoms through VR-based exposure therapy, showing outcomes comparable to traditional Prolonged Exposure Therapy and highlighting its potential as a replicable, cost-effective complement to conventional treatment (Pusey et al. 2022). By partially replacing in-person therapy, VR for exposure therapy reduces time constraints, improves accessibility, supports treatment-resistant individuals, strengthens cognitive and behavioral skills, enhances awareness of automatic thoughts, and

leverages immersion for better perspective-taking (Ito et al. 2023).

For older adults (≥60 years), the prominence of VR Exergames suggests a rising trend in using physical activity-driven interventions for depression. Research confirms exercise's protective effect against depression, linking increased activity to reduced risk (Gianfredi et al. 2020). Exercise influences neurotransmitters, hormones, and brain circuits, periphery-brain communication, contributing to its antidepressant effects (Ren and Xiao 2023). While combining XR-GBI with exercise may introduce conjoined bias, findings support their joint benefits, as XR-GBI enhances engagement and motivation for physical activity (Khundam and Nöel 2021). Additionally, commercial VR exergames outperformed self-developed ones (Peng et al. 2024), emphasizing their cost-effectiveness, accessibility, and superior engagement. Unlike research-developed games, commercial systems offer high-quality graphics, broader accessibility, and increased entertainment value, maximizing user adherence (Pallavicini et al. 2021; Yen and Chiu 2021).

4.3.3 Stress

The findings suggest an emerging but underexplored role of XR-based interventions in stress management, particularly among children and adolescents. No reports in younger populations directly assessed stress, though AR mobile video games showed improvements in selective attention, cognitive control, and sociability, indicating potential stress-relief effects through enhanced emotional intelligence and regulation (Bakır et al. 2023; Reynard et al. 2022). Literature supports video games as potential tools for stress reduction through enjoyable and flow experiences that might promote relaxation (Farmer and Lloyd 2024). Additionally, location-based AR games foster social connections and a sense of belonging (Lawler-Sagarin et al. 2023) while increasing physical activity (Martínez-López et al. 2022), a key factor in stress reduction (Vogel et al. 2022). Nonetheless, the scarcity of literature on stress treatment in children and adolescents may stem from ethical challenges in researching underage participants (Larsson et al. 2021), limiting available data. Indeed, VR-based interventions are subject to age limitations, as producers advise against use by children under 12 because of potential risks such as visual fatigue, disorientation, and safety issues (Pallavicini et al. 2021). Unlike stress treatment, as previously discussed, anxiety interventions using XR-GBI have been widely studied in children and adolescents, especially in hospital and clinical settings for preoperative and procedural care. Although these contexts also require strict ethical considerations (Lagler et al. 2021), they may provide more practical conditions for conducting research. This difference suggests a gap and an opportunity to explore stress-related outcomes in younger populations.

For adults, XR-based interventions for stress and PTSD, primarily using VRET, showed significant symptom reductions. However, long-term efficacy remains uncertain, as one report (Pusey et al. 2022) found VRET comparable to Prolonged Exposure Therapy, but follow-ups at three and six months showed greater PTSD symptom reductions in traditional therapy, suggesting potential limitations in XR-GBI's lasting effects compared to other, more traditional treatments. Also, most reports assessed perceived stress using self-reported questionnaires, a common practice, but incorporating physiological indicators—such as cardiovascular metrics like heart rate variability—could provide more objective and reliable measurements (Vaessen et al. 2021). Digital psychotherapy is gaining traction and can be as effective as in-person therapy, but lags when considering nonverbal and embodied interactions (García et al. 2022). Psychologists report challenges in establishing therapeutic relationships online (Cataldo et al. 2021). Thus, while XR-GBI offers promising mental health benefits, it should complement, rather than replace, psychotherapy by enhancing exposure therapy through controlled virtual environments (Ma et al. 2021).

4.4 Practical and theoretical implications

XR-GBI demonstrates meaningful potential for addressing mental health conditions such as anxiety, depression, and stress, although the risk of bias requires caution when interpreting our results. To clarify the mechanisms underlying these effects, this section outlines the technical features that set XR-GBI apart from other interventions, focusing on presence, immersion, embodiment, multisensory stimulation, and social interaction. Then, we present an integrated theoretical model based on five pathways (cognitive, emotional, bodily, social, and motivational) to support the systematization of XR-GBI and guide future human-computer interaction (HCI) and mental health applications and research.

4.4.1 The XR-GBI features for mental health treatment

The user's sense of presence and immersion are central drivers of the effectiveness of XR-GBI-based therapies based on VR (Bell et al. 2024). Presence is an experiential state within virtual environments, whereas immersion refers to the technical features of a virtual system that support and enhance this experience (Wilkinson et al. 2021). The virtual experience is shaped externally by sensory factors (e.g., visual immersion, resolution, field of view, depth perception,

auditory, gustatory and olfactory cues, frame rate, and real-world distractions) and by content features (e.g., narrative, environmental and avatar realism, appearance, and social interaction), while it is also shaped internally by psychological characteristics (e.g., trait absorption, dissociative and immersive tendencies, locus of control, personality, attention allocation, and cultural determinants) (Felton and Jackson 2022). According to research, immersive and interactive technologies such as VR support learning by strengthening presence and agency, while also enhancing situational interest and embodied learning (Petersen et al. 2022). Immersion in XR can enhance cognitive engagement by fostering greater concentration and attention, creating a flow state that evokes a sense of detachment from time and space (Doğan et al. 2024; Guerra-Tamez 2023). Additionally, this research shows that high interactivity helps lower extraneous cognitive load, which is negatively associated with presence (excessive cognitive load can diminish the learners' sense of presence).

The sense of embodiment in VR arises when users experience a virtual body as their own (shaped by feelings of agency, body ownership, and self-location), referred to as an avatar that can alter perception and behavior, influencing how people act within the virtual environment (Guy et al. 2023). Embodiment emerges as top-down and bottom-up sensory processes shape the internal body model, allowing the system to simulate a body and its surrounding space in ways that mirror real-world action and perception, so that virtual body illusions can effectively modify users' bodily experience through carefully designed avatars and environments (Matamala-Gomez et al. 2021). Embodiment plays a central role in deepening immersion and enabling shifts in how individuals perceive themselves through a virtual body, which can influence attitudes, thinking, and behavior through implicit learning and may support interventions focused on self-related mental health (Geraets et al. 2021). Embodiment can also foster empathy by simulating different physical conditions, allowing users to experience how others navigate the world, making it a powerful tool for understanding diverse perspectives and lived experiences (Guarese et al. 2023).

XR-GBI enables multisensory stimulation, allowing virtual environments to engage multiple senses and evoke specific emotional states, including empathy, by placing users in varied situations and embodied perspectives (Laukkanen et al. 2022). Supported by gameful elements and grounded in XR-GBI principles, these gamified technologies can evoke a range of positive and negative emotions—such as pleasure, surprise, excitement, happiness, anger, frustration, sadness, and fear—by using game-derived dynamics that stimulate these states through cognitive and emotional pathways (Mullins and Sabherwal 2020). Also, all these multisensory stimulations are related to motivation beyond emotions. According to Self-Determination Theory (SDT), motivation spans a continuum from amotivation to extrinsic and intrinsic forms, depending on how well external conditions support an individual's psychological needs (Ryan and Deci 2000, 2020). SDT refers to intrinsic motivation when people engage in activities out of interest, exploration, autonomy, competence, and connection with others, in contrast to extrinsic motivation, which is shaped by external rewards or the avoidance of undesirable outcomes (Di Domenico and Ryan 2017). In this perspective, XR-GBI design may draw on SDT by using specific game elements to influence behavior through multisensory stimulation, encouraging either intrinsic motivation (such as through progress) or extrinsic motivation (such as through rewards) (John et al. 2023).

Finally, beyond presence, immersion, embodiment, and multisensory stimulation, XR-GBI also supports meaningful social interaction through its virtual environments. Virtual reality enables people to relate to themselves, others, and their environment in distinct ways, carrying over many social responses from the physical world while also allowing extensive transformations (such as appearance, behavior, setting, and perspective) that can amplify, reduce, or alter social and environmental cues, ultimately shaping trust, interaction patterns, and nonverbal communication (Han and Bailenson 2024). Social VR applications are increasingly used to support physical and cognitive engagement and to foster connection with geographically distant others through more engaging, presence-rich experiences (Kalantari et al. 2023). Social VR enables selective self-presentation and co-presence through embodied avatars and detailed virtual environments, fostering meaningful connection and engaging social interaction (Hide et al. 2025).

All these five XR-GBI components—presence, immersion, embodiment, multisensory stimulation with emotional and motivational activation, and social interaction—represent technical features that help explain their real-world potential for general application and research. However, while most components were consistently present across reports considered in this study focusing on XR-GBI for mental health, some were absent, revealing important gaps for future research. According to a prior investigation that analyzed the game elements and features of the same XR-GBI interventions included in this umbrella review through reverse engineering of their designs (Coelho and Abreu 2025a), the most frequent game elements within the interventions were emotions, single-player structure, consequence, simulation, customization, meaning, levels, exploration, narrative, and feedback. Thus, according to the research, the interventions were built around elements that promote emotional engagement, individual progression,

meaningful choice, adaptive learning in a simulated environment, personalized avatars, exploratory behavior, structured narrative experience, and continuous guidance—together suggesting elements that foster presence, immersion, embodiment, and multisensory stimulation with a focus on intrinsic motivational drivers. Therefore, these components and game elements appear broadly effective for addressing anxiety, depression, and stress, as our findings indicate an overall neutral to positive impact of XR-GBI on the mental health outcomes examined in this review. Nonetheless, although social features may offer interaction benefits in XR-GBI (Han and Bailenson 2024) and extrinsic motivators can enhance engagement among individuals with lower intrinsic motivation (Liu et al. 2020), both aspects were only marginally explored in the interventions reviewed, indicating a relevant gap for future research, which we address in the next section by proposing a new XR-GBI model.

4.4.2 Integrated Theoretical Model for XR-GBI in Mental Health

Theoretical models serve as exploratory and practical tools that function as cognitive guides for rapid decision-making and system evaluation, while also providing structured frameworks for addressing complex design challenges (Ghisellini et al. 2025; Nizamani et al. 2022). Because much of the work in GBI is developed without a solid theoretical foundation, such models are essential for strengthening research quality by informing both the creation and the assessment of interventions, systems, and study protocols (Coelho and Abreu 2025d).

After examining the full set of data, including the various XR and GBI approaches used to address anxiety, depression, and stress, as well as the features that contribute to their effectiveness, we developed an integrated theoretical model designed to systematize XR-GBI research and applications for mental health, to support the design of future interventions, and to provide a coherent model that synthesizes the evidence reviewed in this umbrella study. The model comprises five interconnected pathways—cognitive, emotional, bodily, social, and motivational.

First, regarding the cognitive pathway, cognition refers to the mental operations and neural processes involved in forming, organizing, and using knowledge about oneself and the environment, as well as the ways this information shapes behavior (D'Esposito et al. 2012; Kihlstrom and Park 2018). Our findings indicate extensive use of CBT and exposure-based methods within XR-GBI as effective cognitive interventions aimed at improving mental health. The simulated settings offered by XR-GBI create controlled, engaging, and flexible scenarios with embodied avatars that help individuals build the competence, confidence, and preparedness needed to confront real-world challenges (Caponnetto et al. 2021). Additionally, individuals can enter a highly focused and rewarding state called "flow" when a task offers enough challenge to prevent boredom yet remains manageable enough to avoid frustration (Chapman et al. 2023; Csikszentmihalyi 2000), which can be promoted by the immersive environments of XR-GBI (Chang et al. 2024). Building on this idea, another study proposed the concept of "fuse", defined as the blending of task-related sensory input with conscious awareness, to describe experiences in which attention becomes fully absorbed in ongoing activity and to refine the cognitive understanding of flow (Jalife et al. 2021). By combining safe simulated experiences with deeply absorbing, task-related sensory engagement, XR-GBI provides an effective means of activating the cognitive pathway in mental health interventions.

Second, concerning the emotional pathway, emotions are subjective states involving physiological reactions and mental evaluations (Luo and Yu 2015), and systematically shape cognitive functioning (Li et al. 2020). Through targeted game elements and mechanics, XR-GBI can be structured to evoke specific emotional responses during interaction (Mullins and Sabherwal 2020). For example, losing "life points" may trigger fear, while earning rewards may elicit happiness, thereby influencing thoughts and behaviors. These emotional shifts also relate to the flow state described earlier (Chapman et al. 2023; Csikszentmihalyi 2000), supporting sustained concentration in a task. Consistent with this idea, XR-GBI has been widely used as a distraction tool to reduce anxiety, changing the attentional aspect, offering deeper immersion than standard audiovisual methods (Yan et al. 2023), and effectively redirecting attention away from stress-inducing stimuli. At the same time, XR-GBI is frequently applied to promote relaxation, leveraging immersive focus to induce calming experiences (Riches et al. 2021). Thus, our findings support this view by showing that XR-GBI can be used for distraction and relaxation, particularly in anxiety-related contexts, demonstrating how emotional stimulation can contribute to improved mental health.

Third, about the bodily pathway, the human body consists of real tissues and fluids that support organ function and our daily life through the epithelial, connective, muscle, and nervous tissues (Neumann and Neumann 2021), and moving that body is important for our mental health. An umbrella review on physical activity and mental health prevention found that higher physical activity levels substantially lowered the likelihood of developing depression and significantly reduced the risk of anxiety (Rahmati et al. 2024). VR-based therapies can enhance both motor and functional abilities by promoting perceptual learning and encouraging physical movement within an immersive environment, making VR training a valuable tool for supporting

cognitive and physical improvement (Ali et al. 2023a, b). Meanwhile, location-based AR can encourage physical activity by prompting users to engage in walking behaviors (Lee et al. 2021). Incorporating game elements into XR experiences can enhance enjoyment, make exercise more engaging, and ultimately promote healthier lifestyle habits (Keppel et al. 2025). Our results align with this literature by showing that XR-GBI is frequently used to encourage physical activity while targeting reductions in depression and stress, connecting the body activation with mental health improvements.

Fourth, referring to the social pathway, despite the limited use of social features and game elements in the interventions reviewed in this study, this pathway remains essential for supporting mental health and warrants greater attention. Social isolation is common among hospitalized patients and youth with mental health conditions who may withdraw due to fear of bullying or conflict (McBride and Preyde 2022). In these contexts, XR-GBI can help ease loneliness by offering accessible opportunities for support and social contact (Guzmán et al. 2024). The immersive and realistic settings of Social VR (or multi-user VR) may deliver advantages beyond traditional therapeutic digital formats such as phone or video sessions, offering psychotherapeutic environments where therapist and patient remain physically apart yet can still establish trust, emotional communication, and a sense of safety, often allowing patients to feel less judged and more open (Matsangidou et al. 2022). Social VR is increasingly applied as a mental health resource, with users reporting improved well-being linked to the anonymity of avatars and the sense of safety in virtual communities, while also using these environments to rehearse social skills, counter negative thinking, and build meaningful connections with others, making it a valuable medium for socialization (Deighan et al. 2023). Still, virtual interaction should complement and not replace face-to-face contact, since offline activities remain essential for well-being (Coelho and Abreu 2025b), positioning XR-GBI as a supportive rather than primary social resource. Moreover, GBI can foster belonging and social connection—key aspects of relatedness within SDT (Li et al. 2024)—which underpins the motivational aspect of the XR-GBI integrated model discussed in the next pathway.

Fifth, concerning the motivational pathway, motivation is a concept explaining human behavior through actions aimed at fulfilling needs and achieving goals (Gopalan et al. 2017). In this sense, as discussed before, the SDT posits that motivation varies from amotivation to extrinsic and intrinsic motivation, with intrinsic motivation, which involves engaging in activities for inherent satisfaction and interest, in contrast to extrinsic motivation, which is driven by achieving external rewards or avoiding punishment (Di Domenico and Ryan 2017; Ryan and Deci 2000, 2020). Our results in this study showed that XR-GBI can be considered a potential tool for supporting mental health, which can also be explained through the enhancement of motivation, engagement, and adherence to healthy behaviors (Gkintoni et al. 2024). Different game elements can support motivation in mental health interventions in distinct ways. For example, avatar-based features relate to the concept of embodiment, in which users experience a virtual body as their own—a process shown to influence attitudes, behaviors, and cognition in ways that benefit psychological health (Aymerich-Franch 2020), which may be related to ownership and autonomy for intrinsic motivation. Likewise, progression game elements such as levels highlight the value of gradual improvement within therapeutic contexts (Krause 2024), aligning with evidence that achievement-oriented motivation is positively linked to mental well-being (Mahdavi et al. 2023), likely reflecting the competence component of intrinsic motivation. As stated before, our findings show that intrinsic motivational features (such as emotional engagement, personal progression, meaningful choices, adaptive simulated learning, avatar personalization, exploration, narrative structure, and ongoing feedback) were central in XR-GBI interventions. These intrinsic components appear valuable for addressing mental health concerns. However, alongside the limited use of social elements within these interventions, the scarcity of extrinsic motivators represents a key gap that needs to be fulfilled, as external rewards can boost engagement among individuals with low intrinsic motivation (Liu et al. 2020), suggesting that incorporating such features may help reach less motivated people.

HCI is central to the development of digital mental health solutions by improving usability, affordability, adaptability, and user value (Balcombe and De Leo 2022). Human-Centered Design (HCD) uses iterative, empathy-driven processes that involve users to create functional and user-friendly systems, with a strong emphasis on shaping meaningful User Experiences (UX), which is essential when developing digital mental health solutions (Sherman et al. 2024; Vial et al. 2022). UX applied to XR-GBI should support the development of meaningful experiences by going beyond functional design to engage users cognitively, emotionally, socially, bodily, and motivationally during digital interaction (Kessing et al. 2024; Scheibler and Rodrigues 2019), positioning UX as a key factor across all pathways discussed in our proposed model. In XR-GBI environments, UX should be used for design, development, evaluation and improvements, by consider four key factors (Kim et al. 2020): (1) user characteristics such as demographics and health status; (2) devices, including input and output hardware; (3) user activity, encompassing interaction types, tasks, partners, and posture; and (4) evaluation methods,

which involve the tools used and the data collected to analyse the experience. Also, UX principles for XR-GBI should integrate playability (encompassing mechanics, dynamics, and aesthetics) with short- and long-term experiential features, while aligning design with XR hardware and budget constraints, ensuring interactions support usability, including interactive tutorials for intuitive control and minimizing discomfort (Martinez et al. 2024). Viewed as an iterative process of continuous refinement based on user feedback, UX should guide all stages of product development, evaluation, and quality assurance for improvements (Crossley et al. 2016). Thus, it is important to highlight that, while we offer some recommendations based on the UX literature discussed here, our integrated theoretical model represents UX as a parallel, interconnected element rather than linking it to a specific framework, allowing flexibility to apply various UX and system development models while reinforcing its relevance across all five features and pathways examined in this study.

Therefore, to visually illustrate our integrated theoretical model, we created a matrix and a framework. The matrix organizes how each XR-GBI feature (presence, immersion, embodiment, multisensory stimulation, and social interaction) contributes to the five theoretical pathways identified in this review (cognitive, emotional, bodily, social, and motivational) to improve mental health. By mapping specific functional effects of each feature onto each pathway, the matrix reveals patterns of overlap, convergence, and complementarity. Table 10 presents the matrix of our theoretical model.

The matrix allows a more detailed visualization of specific relationships between XR-GBI features and the proposed mental health pathways. However, to better illustrate how these features interact with the pathways, we developed a framework that highlights potential connections between them. The matrix supports the grouping of features into categories, forming the basis for the framework's theoretical model. Based on our umbrella review and the matrix in Table 10, XR-GBI features (presence, immersion, embodiment, multisensory stimulation, and social interaction) may be grouped in three functional categories: attentional and perceptual absorption; social presence and interpersonal meaning; and embodied sensorimotor action. These categories interact with the five pathways (cognitive, emotional, bodily, social, and motivational), which may also combine in specific ways, forming three key processes: self-regulation and exposure processing; behavioral activation and engagement; and social connectedness and role competence. Together, these processes may support improvements in mental health, such as reduced anxiety, depression, and stress. Additionally, in parallel with the relationship between features and pathways, UX principles should account for key factors for both short- and long-term experience, such as user characteristics, device and budget constraints, user activity and playability, usability and tutorials, and evaluation methods for quality assurance and data analysis (Kim et al. 2020; Martinez et al. 2024). Figure 7 illustrates the proposed framework.

Based on the analysis of XR-GBI interventions and their effects on anxiety, depression, and stress, XR-GBI emerges as a promising approach for mental health care. By organizing its potential into five technical features, interconnected pathways, and processes that influence these conditions in distinct yet complementary ways, we propose an integrated theoretical model (with a matrix and a framework) illustrating how all these elements may contribute to better mental health. We encourage future research to use this model when designing and evaluating XR-GBI systems and study protocols, as it may help identify strengths and limitations to guide the development of more effective interventions. However, it is important to note that this model is illustrative, grounded in the findings and theoretical insights of this umbrella review, and has not yet been empirically tested, an essential step for future research.

5 Conclusion

In this umbrella review, we jointly examine XR and GBI rather than treating them separately, to harmonize and map XR-GBI purposes across mental health conditions and age groups, applying a unified AMSTAR 2 risk-of-bias assessment across all reviews, offering a more comprehensive understanding of the literature. This study underscores the promising potential of XR-GBI in addressing anxiety, depression, and stress, with evidence demonstrating preliminary consistent symptom reduction across all age groups. This review indicates that XR-GBI offers promising early evidence as a flexible, cost-effective, and replicable approach to mental health care, particularly when integrated into psychotherapy as a complementary tool for enhancing traditional treatments. However, it is crucial to highlight that across all included reviews, confidence was rated low or critically low, primarily due to missing excluded-study lists, absent review protocols, and undisclosed funding sources—issues that reduce transparency, increase risk of bias, and conflict with Cochrane Recommendations standards for methodological rigor. These limitations, combined with the lack of external validity reporting in the reports considered in this umbrella review, highlight the need for more robust and transparent research practices to strengthen the reliability and generalizability of the findings presented here.

Table 10 XR-GBI integrated theoretical model—matrix

		Theoretical model pathways				
		Cognition	Emotions	Body	Social	Motivation
XR-GBI features	Presence	Locus of control; enhances attention; reduces distractions; supports cognitive restructuring in exposure and learning	Intensifies emotional engagement through perceived realism and agency; supports relaxation	Strengthens meaningful motor responses for perceived realism and increased participation in tasks through enhanced locus of control	Increases the realism of social cues in social interactions and environments	Makes therapeutic tasks feel relevant and personally meaningful, supporting intrinsic motivation for competence
	Immersion	Reduces extraneous cognitive load; increases cognitive engagement, focus, learning, and flow state	Enhances distraction effects during procedures; flow state through detachment of time and space; deepens emotional involvement	Encourages active movement; improves sensorimotor integration through immersive tasks	Heightens perceived social realism in simulated social environments	Creates engaging, rewarding environments that improve adherence, enjoyment, and flow state
	Embodiment	Supports transfer of learning and cognitive-behavioral mechanisms by simulating agency and perceived embodied cognition	Modulates emotional responses via body ownership and self-location; enhances empathy by simulated living experiences	Promotes physical engagement; enhances body awareness for movement	Enables safe practice of social roles; reduces fear of judgment and increases empathy	Strengthens autonomy and ownership through avatar personalization; increases long-term adherence
	Multisensory stimulation	Guides attention; permits concentration or distraction; enhances cognitive control and perceptual learning	Promotes relaxation; game dynamics evoke emotional engagement through positive and negative emotions	Supports physical activation; enhances sensorimotor learning	Shapes interpretation of social context, favouring empathy; simulates the rich sensorial scenario of real or fictional environments; reinforces nonverbal cues	Sensory richness increases enjoyment; game elements influence behavior via multisensory stimulation by intrinsic or extrinsic motivational cues
	Social interaction	Supports role-play and social cognitive skill practice in social contexts	Stimulates emotions related to social connection and presence; enhances emotional regulation; reduces distress during social exposure	Encourages embodied communication (gestures, posture)	Builds connectedness; reduces isolation; supports social learning and well-being	Adds relatedness, supporting intrinsic motivation, and boosts engagement through cooperation/competition

The dominance of VR as the primary intervention highlights XR's role in simulated exposure, CBT, distraction, relaxation, and promoting physical exercise. However, the underutilization of AR and MR represents a significant research gap, as these technologies could enhance real-world integration, foster social interactions, and improve accessibility. Additionally, while serious games are widely employed due to their focus on goal-oriented, fully developed games for therapy, embedding educational objectives into engaging gameplay, gamification, and game-based learning and training remain underexplored tools that could significantly boost motivation, engagement, education, and cognition in XR-based mental health interventions.

Furthermore, there is a heavy reliance on subjective assessments and diagnoses, while biofeedback and neurophysiological tools remain underutilized, despite their potential to provide more objective diagnostics, improve intervention adaptability, and enhance treatment precision. Also, XR-GBI research focuses on individual-based interventions, with limited exploration of social therapy formats, despite compelling evidence supporting social engagement as a critical factor in mental health improvement.

Finally, drawing on our results, we outline practical and theoretical implications by demonstrating that XR-GBI are supported by key technical features that permit presence, immersion, embodiment, multisensory stimulation, and social interaction. To integrate all the insights from this review, we introduce an integrated theoretical model comprising five interconnected pathways—cognitive, emotional, bodily, social, and motivational—that together systematize the mechanisms through which XR-GBI may foster mental health improvements. This model provides a structured basis for future system design, evaluation, and research, enabling clearer identification of strengths and gaps to support the development of more effective XR-GBI for mental health.

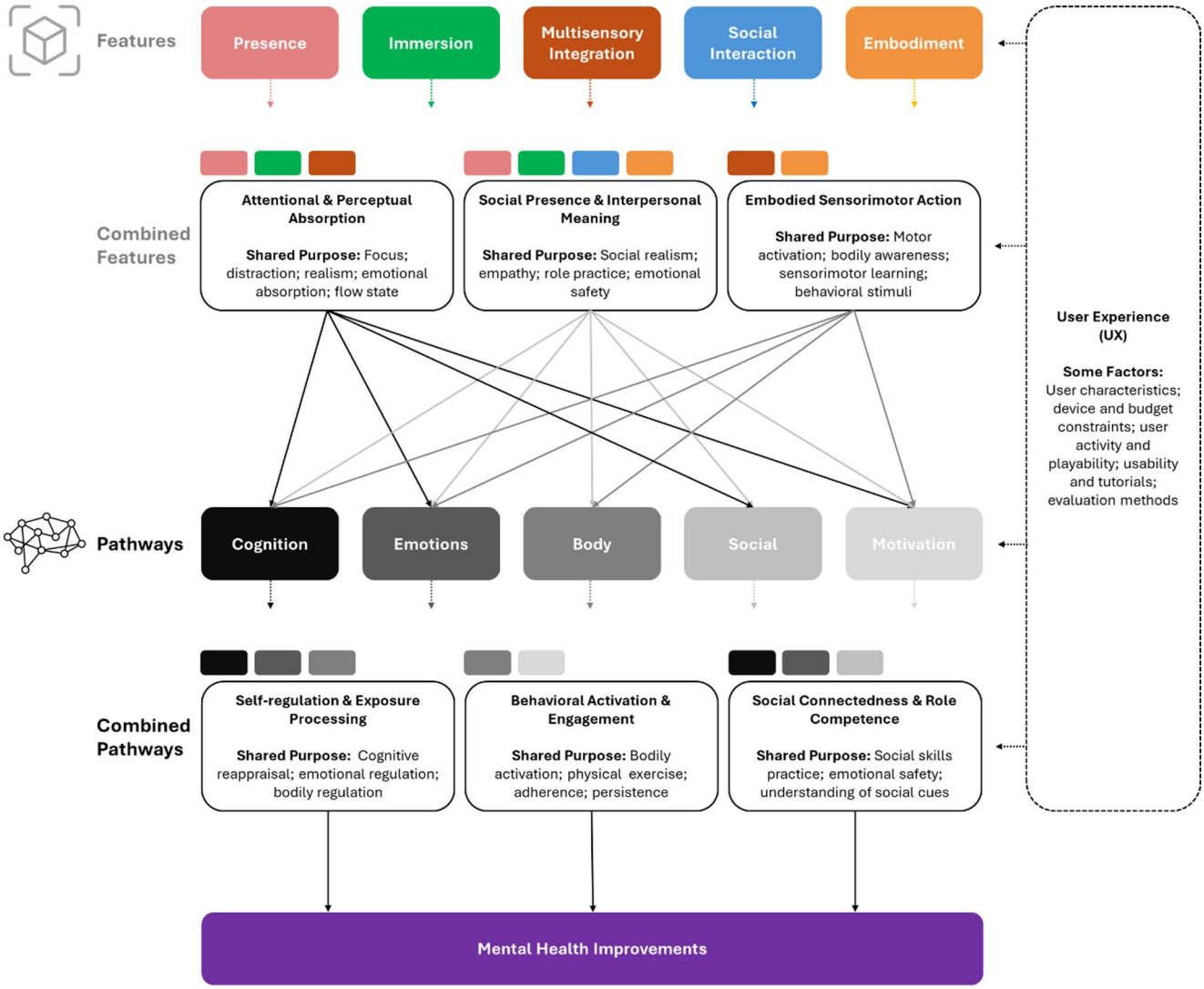

Fig. 7 XR-GBI integrated theoretical model—framework

6 Limitations

The reports included were restricted by the search terms and databases used in this review. However, despite these constraints, the selection provides meaningful insights into the current state of research on XR-GBI for mental health, offering an overview of how these interventions impact cognition and emotional well-being.

First, it is important to recognize that all included reviews received low or critically low confidence ratings, reflecting shortcomings in transparency, elevated risk of bias, and deviations from the methodological standards outlined in the Cochrane Recommendations (Higgins et al. 2023). These concerns, combined with the absence of external validity assessment in the reports, underscore the need for clearer and more rigorous research procedures to improve the generalizability and replicability of the evidence, particularly regarding the sample aspects, like participant selection, allocation, and representativeness (Khorsan and Crawford 2014). In addition, the extensive reliance on self-report instruments to assess mental health symptoms introduces the possibility of response bias in the outcomes (Anvari et al. 2023). Taken together, these issues related to internal and external validity, along with the limitations of subjective measurement, represent meaningful constraints that must be considered when interpreting the present results.

For selection criteria, we applied PICO, PRISMA, and Cochrane Collaboration guidelines (Higgins et al. 2023; Page et al. 2021; Pati and Lorusso 2018), prioritizing RCT as the gold standard of experimental research, given that randomization minimizes bias and enhances the strength of causal inferences (Hariton and Locascio 2018). Nonetheless, as a result, we excluded qualitative studies, despite their potential to offer insights into user experiences and

intervention perceptions (Cavalcanti et al. 2021; Fernández-Vázquez et al. 2024). Since GBI involves playful elements, some studies use exploratory and observational methods to ensure external validity and generalizability, contributing to a broader understanding of XR-GBI effectiveness (Khorsan and Crawford 2014). While focusing on RCT allowed causal comparisons between XR-GBI and non-XR-GBI, it may have limited findings, particularly those explored in qualitative and observational research.

As our research was already restricted to RCT, we included studies with various control groups, such as waiting lists, treatment as usual, other active treatments, or no intervention. While control groups are crucial for proving an intervention's effectiveness, comparisons with inactive controls only show that it is better than receiving no treatment, without assessing its effectiveness against other active treatments (Staudacher et al. 2017). Thus, our findings should be viewed with this limitation, as some RCT compared XR-GBI with other therapies, while others did not, reducing the strength of comparisons with alternative treatments. Additionally, it is important to note that our analysis of XR-GBI impact is based on comparisons with the specific control groups used in the included reports (e.g., treatment as usual, such as conventional CBT). As such, any comparative claims are limited to those specific comparators and should not be interpreted as general comparisons with any other interventions. Although analyzed separately, anxiety, depression, and stress often overlap, particularly in PTSD-related depression or stress-induced anxiety, highlighting the need for a holistic mental health approach to XR-GBI (Gass 2023). Additionally, VR interventions face age restrictions, as manufacturers discourage use in children under 12 due to cognitive confusion, eye strain, and safety concerns (Pallavicini et al. 2021). This likely restricts XR-GBI studies in younger populations, emphasizing the need for age-appropriate interventions.

Inconsistent classification of VR and GBI complicates research. Some reports label television-based and projector interactions as VR (Peng et al. 2024; Yen and Chiu 2021), potentially overgeneralizing immersion, while cave-based projections offer deeper engagement (Cruz-Neira et al. 2023). Likewise, some XR-GBI programs resemble interactive films rather than true games with active player involvement (Kulakaç and Ustuner Top 2025; Wang et al. 2024). This review followed the classifications provided in the original reports, but vague descriptions and heterogeneous technologies limit standardization and reveal substantial variation in equipment and software, making comparisons across interventions difficult. Clearer differentiation between immersive VR, interactive media, and GBI—along with greater consistency in technologies and protocols—is essential to improve replicability and reduce bias in effect evaluation.

Finally, the XR-GBI integrated theoretical model proposed in this study was developed with an illustrative purpose to systematically synthesize the findings of this umbrella review and support future research on XR-GBI and mental health. However, the model has not been empirically tested or validated, and therefore, its interpretation and generalization should be approached with caution.

7 Recommendations and future research

As stated previously, the underuse of AR and MR presents a research gap, as these could potentially enhance real-world integration, social interaction, and accessibility. While serious games are common, gamification and game-based learning and training remain underutilized despite their potential to impact mental health through XR-GBI. Research relies heavily on subjective assessments, with biofeedback and neurophysiological tools underused despite their diagnostic value. Recent progress in XR (such as improved haptics, body and facial tracking, multisensory integration, and interoceptive signal modulation) has strengthened social presence, enhanced interpersonal synchrony, and expanded avatar customization, enabling more natural and meaningful interactions (Fusaro et al. 2025). XR-GBI primarily focuses on individual therapy, with limited exploration of social therapy. Additionally, physiological markers like facial expressions, biosensors, and heart rate can assess stress and anxiety while adapting gameplay for immersion, as in the XR-GBI named "Deep", which uses biofeedback to track diaphragm movement, enabling players to navigate the game through slow, deep breathing (Sajjadi et al. 2022; van Rooij et al. 2016). Also, the metaverse enables studying social interactions through hyperscanning and interbrain synchrony, offering insights into group dynamics beyond traditional methods (Maslova et al. 2025). Therefore, future studies should explore these applications and integrate AR, MR, gamification, game-based learning and training, neurophysiological tracking, and social elements to expand XR-based mental health interventions.

Despite XR-GBI's potential, high costs, and limited accessibility of immersive devices hinder implementation (Tori et al. 2022). Stronger collaborations between the gaming industry, researchers, and healthcare providers could bridge this gap, advancing technology for holistic clinical integration (Dewhirst et al. 2022). Indeed, the role of artificial intelligence (AI) in XR-GBI remains underexplored. Future research should examine adaptive game mechanics (Shashikala et al. 2024), biofeedback-driven gameplay (Williams 2021), generative AI and embodied virtual

human assistants (Chheang et al. 2024), and AI-enhanced CBT (Jiang et al. 2024), enabling real-time cognitive and emotional adaptation and customization. AI also boosts efficiency, reduces costs, and improves software quality (Sauvola et al. 2024), making XR-GBI more accessible. Advancing AI integration could enhance customization, interactivity, and replicability, strengthening XR-based mental health interventions.

Future studies should incorporate exploratory and observational research to complement quantitative data and refine XR-GBI interventions. Examining user perspectives on XR-GBI models could improve intervention design and software development. XR-GBI was primarily used as a distraction and enjoyment tool for children, anxiety and depression treatment for adults, and depression treatment through exergames for older adults, yet all approaches could benefit diverse age groups. Expanding research on underexplored mental health issues across populations could enhance public mental health strategies. XR-GBI's potential to foster empathy through perspective-taking (Trevena et al. 2024) should also be explored beyond therapy, including applications in mental health education and prevention, such as anti-bullying programs (Liu et al. 2023). This presents a significant opportunity for expanding digital mental health literacy and psychoeducation (Yeo et al. 2024).

Finally, future research could build on the technical features (presence, immersion, embodiment, multisensory stimulation, and social interaction) and the five XR-GBI pathways (cognitive, emotional, bodily, social, and motivational) highlighted in this umbrella review to ensure interventions fully leverage the potential of this technology. By providing these systematizations, we hope future XR-GBI studies and applications can rely on a unified model, enabling comparison across interventions and guiding new developments. By doing so, the integrated theoretical model may help maximize XR-GBI's impact and effectiveness in improving mental health outcomes related to anxiety, depression, stress, and potentially other issues that warrant further exploration.

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Declarations

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