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Mapping VR, AR, and AI-Based Mental Health Interventions: A Bibliometric Analysis, 1996–2024

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Abstract

This study maps the development, scholarly impact, thematic structure, and international collaboration patterns of research on virtual reality (VR)-, augmented reality (AR)-, and artificial intelligence (AI)-based mental health interventions. Bibliographic records were retrieved from Scopus on November 7, 2024, and analyzed using Biblioshiny. The dataset comprised 282 documents published between 1996 and 2024; therefore, the 2024 publication count represents partial-year coverage. Descriptive performance analysis, citation analysis, co-authorship analysis, keyword co-occurrence mapping, and topic-trend analysis were applied. The literature showed an annual growth rate of 14.47%, an average of 25.94 citations per document, and an international co-authorship rate of 19.15%. The United States, the United Kingdom, and Italy were prominent contributors, whereas Africa, South America, and many low- and middle-income countries remained underrepresented. The citation and thematic structures were dominated by VR, particularly virtual reality exposure therapy for posttraumatic stress disorder, anxiety, and phobias. AR- and AI-related therapeutic applications were included in the broader research landscape but were less prominent in the mapped networks and influential-document rankings. By examining VR, AR, and AI within a single bibliometric framework, this study identifies imbalances in technological maturity, therapeutic focus, and global research participation. Future progress requires stronger clinical validation, transparent and reproducible methods, culturally adapted interventions, ethical governance, cost-sensitive implementation, and more equitable international collaboration.

Keywords: Virtual Reality; Augmented Reality; Artificial Intelligence; Mental Health; Digital Therapeutics; Bibliometric Analysis

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INTRODUCTION

Mental health disorders, including anxiety and depression, impose substantial burdens on individuals, families, health systems, and communities. Established treatments, particularly cognitive behavioral therapy (CBT) and pharmacotherapy, are effective for many patients (Jalil et al., 2024; David et al., 2018). However, their reach and effectiveness may be constrained by limited service availability, treatment costs, stigma, geographic barriers, and variation in individual responses. These challenges have increased the need for accessible, adaptable, and scalable mental health interventions, particularly for underserved populations and settings (Castro et al., 2023; Weaver & Himle, 2017).

Virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) offer complementary approaches to technology-assisted mental health care. VR creates controlled immersive environments, whereas AR integrates digital stimuli into real-world settings; both can support structured therapeutic activities, including exposure-based interventions (Ficarra, 2020). AI can support symptom assessment, pattern detection, treatment personalization, and conversational mental health applications, although these uses require appropriate professional oversight (Khawaja & Bélisle-Pipon, 2023).

Despite rapid growth in this literature, the evidence remains fragmented across technological modalities. Previous reviews have primarily examined VR therapy (Emmelkamp & Meyerbröker, 2021), AI-enabled tools for anxiety and depression (Pavlopoulos et al., 2024), or VR and AR applications in medicine more broadly (Yeung et al., 2021). Other syntheses have evaluated technology-mediated psychotherapy without directly comparing the development of VR, AR, and AI research (Greenwood et al., 2022). Consequently, limited evidence is available on how these technologies collectively shape the mental health research landscape, how their thematic development differs, and how research participation and collaboration are distributed geographically.

Bibliometric analysis provides a systematic method for examining publication growth, citation influence, productive sources, institutional participation, international collaboration, and thematic development. This study therefore maps VR-, AR-, and AI-based mental health interventions within a single bibliometric framework. Rather than assuming that the three technologies are equally represented, the analysis evaluates their relative visibility and identifies imbalances in technological maturity, clinical focus, and global research participation.

Study Scope

The study examined English-language documents indexed in Scopus and published between 1996 and 2024. It focused on publications addressing VR-, AR-, and AI-based therapeutic interventions in mental health. Methodological limitations related to database coverage, language restrictions, citation lag, and search-term sensitivity are addressed in the Methods section.

Research Questions

This study addressed the following research questions:

1. How did publication output and citation impact in VR-, AR-, and AI-based mental health interventions evolve between 1996 and 2024?
2. Which authors, institutions, sources, and countries contributed most prominently, and how were international collaborations distributed?
3. Which thematic areas, recurring concepts, and emerging topics were identified through keyword and co-occurrence analyses?
4. Which publications and research domains had the greatest scholarly influence, and what gaps remained in technological representation, geographic diversity, and clinical application?

Objectives of the Study

The primary objective was to map the research landscape of VR-, AR-, and AI-based therapeutic interventions for mental health. The specific objectives were to:

1. analyze annual publication growth and citation patterns;
2. identify leading authors, affiliations, sources, and countries;

3. map co-authorship and international collaboration networks;
4. examine thematic clusters and the evolution of research topics; and
5. identify influential publications and gaps requiring further investigation.

Significance and Contribution

This study provides researchers, clinicians, policymakers, and funding organizations with an integrated overview of technology-assisted mental health research. Its principal contribution lies in jointly examining VR, AR, and AI while identifying differences in their scholarly maturity and thematic prominence. The study also evaluates geographic and collaboration patterns, thereby revealing areas in which research participation remains concentrated or underrepresented. These findings can inform research priorities, international partnerships, funding strategies, and the development of clinically relevant and contextually appropriate mental health technologies.

Literature Review

Technology-Assisted Mental Health Interventions

VR, AR, and AI support different but potentially complementary forms of mental health intervention. VR provides fully immersive environments, AR embeds digital therapeutic stimuli within real-world contexts, and AI enables data-driven assessment, personalization, monitoring, and conversational support. Their clinical value depends not only on technological capability but also on therapeutic design, patient characteristics, clinician involvement, usability, and ethical governance.

Virtual Reality in Mental Health Interventions

VR has been studied extensively because it enables therapists to create controlled, repeatable, and adjustable therapeutic environments. Virtual reality exposure therapy is particularly relevant to anxiety disorders, phobias, social anxiety, and posttraumatic stress disorder because patients can confront feared situations without reproducing them physically. Evidence indicates that VR-based exposure can produce outcomes comparable to conventional in vivo exposure for selected conditions while offering greater control over stimulus intensity and therapeutic pacing (Emmelkamp et al., 2020; Riva et al., 2019).

VR has also been incorporated into cognitive and mindfulness-based interventions by providing structured environments that support attention, relaxation, and emotional regulation (Lindner, 2021). Nevertheless, implementation may be limited by equipment costs, technical requirements, user discomfort, and cybersickness. The clinical value of VR therefore depends on balancing immersion and therapeutic flexibility with safety, usability, and patient acceptance.

Augmented Reality in Therapeutic Contexts

Unlike VR, AR overlays digital objects or information onto the user's physical surroundings. This feature makes AR particularly suitable for interventions that require interaction with therapeutically relevant stimuli in a real-world context. In exposure therapy for specific phobias, for example, virtual stimuli can be introduced gradually into the patient's immediate environment, allowing the intervention to be adjusted according to individual tolerance and progress (Albakri et al., 2022; Jurcik et al., 2024; Toffolo et al., 2022).

AR may also support behavioral training and CBT-related activities by delivering therapeutic content in familiar settings. Its portability may reduce reliance

on repeated clinic-based sessions and could improve access in areas with limited mental health services (Yeung et al., 2021). However, AR research remains less extensive than VR research, and further evidence is required regarding its comparative effectiveness, long-term outcomes, usability, and safety.

Artificial Intelligence in Mental Health Care

AI applications in mental health include machine-learning models for risk prediction, natural language processing, clinical decision support, treatment personalization, and conversational agents. Predictive algorithms can analyze clinical and behavioral data to identify patterns associated with treatment response or changes in depressive symptoms, potentially supporting earlier and more individualized intervention (Lee et al., 2018).

AI-enabled chatbots can deliver psychoeducation, CBT-informed exercises, symptom monitoring, and structured conversational support. Existing studies suggest that these systems may improve access to basic mental health resources and provide support outside conventional service hours (Omarov et al., 2023; Pavlopoulos et al., 2024). However, their effectiveness may vary according to intervention design, user needs, and the presence of professional supervision. AI-generated interactions also cannot be assumed to provide the empathy, contextual judgment, or clinical responsibility associated with a qualified therapist (Khawaja & Bélisle-Pipon, 2023).

Effectiveness and Implementation Considerations

Technology-assisted therapies may improve engagement, accessibility, treatment adherence, and personalization for selected conditions. Evidence suggests that some digitally mediated psychological interventions can achieve outcomes comparable to face-to-face treatment, although effectiveness varies across clinical conditions and delivery models (Greenwood et al., 2022). VR offers immersive and controlled therapeutic experiences, AR enables contextual interaction with digital stimuli, and AI can provide scalable assessment and support.

These advantages are not distributed equally across populations. Older adults, individuals with disabilities, and people with limited digital literacy or inadequate technological access may experience greater implementation barriers. Outcomes can also be influenced by patient confidence with technology, clinician support, intervention setting, interface design, and the availability of technical assistance. Technology-assisted interventions should therefore be adapted to individual and contextual needs rather than implemented as uniform solutions (Alruwaili et al., 2023; Vailati Riboni et al., 2020).

Ethical and Evidence-Related Challenges

The use of VR, AR, and AI in mental health introduces concerns regarding privacy, informed consent, data security, transparency, and clinical accountability. These concerns are especially important for AI systems that process sensitive psychological data or generate recommendations for vulnerable users. Patients and clinicians must be able to understand how data are used and when automated outputs require professional review (Espejo et al., 2023; Terra et al., 2023).

The evidence base also remains methodologically uneven. Many interventions have been evaluated in small or narrowly defined samples, limiting the generalizability of findings. Long-term therapeutic outcomes, adverse effects, comparative effectiveness, and implementation across diverse cultural and health-care settings require further investigation. These gaps support the need for

bibliometric mapping that identifies where research has concentrated and where technological, clinical, and geographic imbalances remain.

METHOD

Study Design

This study employed bibliometric analysis and science mapping to examine publication trends, scholarly contributions, citation impact, collaboration patterns, and thematic developments in research on technology-assisted mental health interventions, with a particular focus on virtual reality (VR)-, augmented reality (AR)-, and artificial intelligence (AI)-based therapies (Donthu et al., 2021).

Data Source and Search Strategy

Bibliographic records were retrieved from the Scopus database on November 7, 2024. Scopus was selected because of its broad interdisciplinary coverage of health sciences, psychology, computer science, and technology-related research (Falagas et al., 2008).

The search strategy combined terms referring to VR-, AR-, and AI-based therapies with terms related to mental health, depression, and anxiety. The search was applied to document titles, abstracts, and keywords using the following Scopus search string:

> *TITLE-ABS-KEY(("virtual reality therapy" OR "VR therapy" OR "augmented reality therapy" OR "AR therapy" OR "artificial intelligence therapy" OR "AI therapy") AND ("mental health" OR depression OR anxiety)) AND PUBYEAR > 1995 AND PUBYEAR < 2025 AND LIMIT-TO(LANGUAGE, "English")*

The publication-year limits restricted the dataset to documents published between 1996 and 2024. Only English-language records containing the specified terms in their titles, abstracts, or keywords were retained. Because the data were retrieved on November 7, 2024, the publication count for 2024 represents partial-year coverage.

Document Screening and Selection

The records retrieved from Scopus were screened for relevance to therapeutic applications of VR, AR, and AI in mental health. Documents were retained when their titles, abstracts, or keywords addressed technology-assisted therapeutic interventions related to mental health conditions, including depression and anxiety. Records that did not meet the thematic and language eligibility criteria were excluded. Following the screening and selection process, 282 documents were included in the bibliometric analysis. Figure 1 summarizes the workflow for identifying, screening, and selecting documents included in the bibliometric analysis.

Data Processing

Bibliographic metadata, including author names, publication years, source titles, keywords, citation counts, and institutional affiliations, were exported from Scopus and processed using Biblioshiny, the web-based interface of the Bibliometrix package in R (Aria & Cuccurullo, 2017). The data were examined for consistency before the bibliometric indicators and visualization outputs were generated.

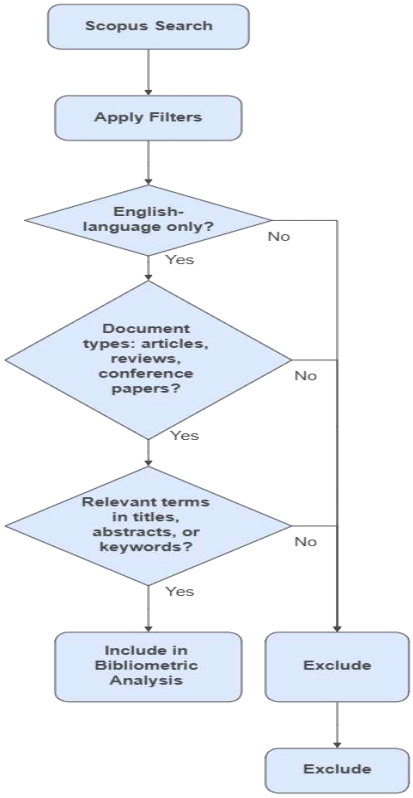

Figure 1. Workflow for identifying, screening, and selecting documents included in the bibliometric analysis.

Analytical Methods

Descriptive performance analysis was conducted to evaluate annual publication growth, source productivity, authorship characteristics, geographic participation, document types, and citation impact. Co-authorship analysis was used to examine collaboration patterns among authors and countries, while keyword co-occurrence analysis was conducted to identify prominent concepts, thematic clusters, and emerging research topics. Citation analysis was applied to assess the scholarly influence of documents and publication sources (Zupic & Čater, 2015).

Country-level indicators were interpreted according to their respective units of analysis. Corresponding-author country data represented the number of documents attributed to the country of the corresponding author. In contrast, author-country occurrences represented the frequency with which countries appeared in authors' affiliation records. Consequently, author-country occurrence values could exceed the total number of documents because a single publication may include authors from multiple countries.

Biblioshiny was used to generate annual production trends, citation indicators, source rankings, co-authorship networks, keyword co-occurrence maps, thematic clusters, trending-topic visualizations, and international collaboration maps. These complementary analyses enabled an integrated assessment of the field's development, intellectual structure, scholarly influence, and collaboration patterns (Aria & Cuccurullo, 2017; Donthu et al., 2021).

Methodological Limitations

This study has several methodological limitations. First, reliance on Scopus as the sole bibliographic database may have excluded relevant documents indexed only in other international or regional databases. Although Scopus offers broad

interdisciplinary coverage, its indexing scope may underrepresent publications from certain regions and non-English-speaking research communities (Falagas et al., 2008). The restriction to English-language records may have further limited the geographic and linguistic diversity of the dataset.

Second, bibliometric indicators depend on the completeness and consistency of database metadata. Variations in author names, institutional affiliations, country designations, and indexed keywords may therefore have influenced estimates of research productivity and collaboration. Third, citation-based indicators are affected by citation lag, particularly for recently published documents. Citation values for publications from 2023 and 2024 should therefore be interpreted cautiously. The 2024 publication count should also be regarded as provisional because the data were retrieved before the end of the calendar year.

Fourth, the composition of the dataset depended on the selected search terms and Scopus indexing practices. Relevant studies using alternative terminology for VR-, AR-, AI-, or technology-assisted mental health interventions may not have been retrieved. Bibliometric analysis was selected because it enables large-scale mapping of publication trends, citation impact, collaboration networks, and thematic structures rather than the synthesis of clinical effect sizes expected in systematic reviews or meta-analyses (Donthu et al., 2021; Zupic & Čater, 2015). Future studies should integrate multiple databases and multilingual sources to improve coverage, representation, and comprehensiveness.

RESULTS AND DISCUSSION

Dataset Characteristics

As summarized in Figure 2, the dataset comprised 282 documents published between 1996 and 2024 across 199 sources, including journals, books, and conference proceedings. The literature showed an annual growth rate of 14.47%, indicating a sustained increase in scholarly interest in technology-assisted mental health interventions. Because the data were retrieved on November 7, 2024, the publication count for 2024 represents partial-year coverage.

The mean document age was 6.07 years, indicating that a substantial proportion of the literature was published relatively recently. The documents received an average of 25.94 citations each and collectively cited 10,974 references, demonstrating that the field draws on an extensive and interdisciplinary knowledge base.

Figure 2. Summary characteristics of the bibliometric dataset on virtual reality (VR)-, augmented reality (AR)-, and artificial intelligence (AI)-based mental health interventions, 1996–2024.

The dataset contained 2,180 indexed keywords (ID) and 764 author keywords (DE). This diversity reflects the intersection of mental health, psychology, clinical treatment, computer science, immersive technology, and artificial intelligence represented in the literature.

Authorship indicators also showed a predominantly collaborative research structure. A total of 1,206 authors contributed to the 282 documents, whereas only 18 documents were written by a single author. The mean number of co-authors was 5.57 per document, and 19.15% of the documents involved international co-authorship. These results indicate that collaboration was common, although cross-country collaboration remained limited to fewer than one-fifth of the analyzed documents.

Journal articles represented the largest document category, with 171 records, followed by conference papers (53), reviews (36), book chapters (12), and editorials (4). These listed categories accounted for 276 documents, while the remaining records were distributed across other document types represented in the dataset. The predominance of journal articles and conference papers reflects the simultaneous development of clinical evidence and technological innovation in this research area.

Annual Scientific Production and Citation Trends

Figure 3 presents the annual publication output and citation indicators for research on VR-, AR-, and AI-based mental health interventions. Scientific production remained limited during the early period, with approximately one to five publications per year between 1996 and 2003. Publication output subsequently increased, particularly after 2007, and reached 44 documents in 2024. However, this value should be interpreted as a partial-year count because the data were retrieved on November 7, 2024.

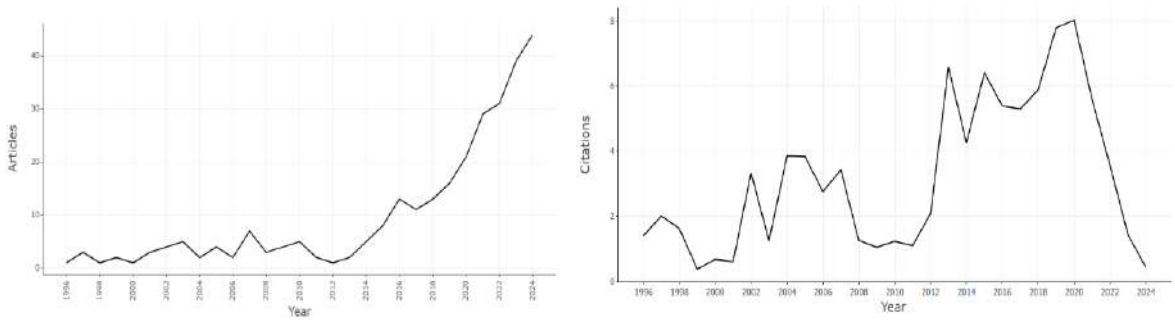

Figure 3. Annual scientific production and mean citation impact of publications on VR-, AR-, and AI-based mental health interventions, 1996–2024.

The mean total citations per publication, reported in Biblioshiny as MeanTCperArt, varied considerably across publication years. Documents published in 1997 and 2002 received mean total citation values of 56.33 and 76.75, respectively. These relatively high values indicate that some early publications became influential references in the subsequent development of technology-assisted mental health research.

Mean citation values were lower for more recent publication years. Publications from 2021 and 2022 received mean total citation values of 22.41 and 10.71, respectively, whereas publications from 2023 and 2024 recorded values of 2.90 and 0.43. This decline primarily reflects citation lag because recently published documents have had less time to accumulate citations. Therefore, citation indicators for the latest

publication years should not be interpreted as evidence of lower scientific quality or relevance.

Overall, Figure 3 demonstrates a clear increase in publication activity, particularly from 2019 onward. The simultaneous rise in annual output and decline in recent citation averages reflects the rapid expansion of the field and the time-dependent nature of bibliometric citation indicators.

Leading Publication Sources

Table 1 compares source productivity with local citation impact within the analyzed dataset. Studies in Health Technology and Informatics was the most productive source, with 14 documents, and also showed strong local influence, with an h-index of 8, a g-index of 14, and 283 total citations. Its first publication represented in the dataset appeared in 1997, indicating a longstanding contribution to the field.

Table 1. Most productive sources and local citation impact of leading publication sources

Most productive sources	Documents	Most locally cited sources	h-index	g-index	m-index	TC	NP	PY_start
Studies in Health Technology and Informatics	14	Studies in Health Technology and Informatics	8	14	0.286	283	14	1997
Cyberpsychology and Behavior	7	Cyberpsychology and Behavior	6	7	0.231	665	7	1999
Frontiers in Psychiatry	6	Journal of Medical Internet Research	5	5	1.000	164	5	2020
JMIR Mental Health	6	Breast Cancer Research and Treatment	4	4	0.267	85	4	2010
JMIR Serious Games	5	Frontiers in Psychiatry	4	6	0.500	319	6	2017
Journal of Medical Internet Research	5	Frontiers in Psychology	4	4	0.571	133	4	2018
Annual Review of Cybertherapy and Telemedicine	4	JMIR Serious Games	4	5	0.571	213	5	2018
Breast Cancer Research and Treatment	4	International Journal of Environmental Research and Public Health	3	3	0.750	49	3	2021
Frontiers in Psychology	4	JMIR Mental Health	3	6	0.333	149	6	2016
JMIR Research Protocols	4	JMIR Research Protocols	3	4	0.600	21	4	2020

Note: TC = total citations; NP = number of publications; PY_start = first publication year represented in the dataset.

Cyberpsychology and Behavior published seven documents and recorded 665 total citations, the highest citation count among the sources listed in the local-impact panel. Its h-index of 6 and first represented publication in 1999 indicate that it contributed several early and influential studies on technology-assisted psychological interventions.

More recently established sources also showed substantial influence. Journal of Medical Internet Research recorded an h-index and g-index of 5, while Frontiers in Psychiatry recorded an h-index of 4, a g-index of 6, and 319 total citations. JMIR Mental Health, JMIR Serious Games, Frontiers in Psychology, and JMIR Research Protocols further demonstrate the importance of interdisciplinary outlets connecting mental health, digital health, serious games, and clinical informatics.

The inclusion of Breast Cancer Research and Treatment among the productive and locally cited sources indicates thematic overlap with research on psychological well-being, treatment outcomes, and quality of life in medical populations. However, its presence should not be interpreted as evidence that all associated publications directly examined VR-, AR-, or AI-based mental health treatment without document-level verification.

Leading Affiliations and Corresponding-Author Countries

Table 2 presents the leading institutional affiliations and the most productive countries based on the corresponding authors' affiliations. The University of Oxford recorded the highest number of affiliation occurrences, with 99, followed by the University of Pittsburgh with 30 and the McPin Foundation with 15. Johns Hopkins University recorded 14 occurrences, while several academic and clinical institutions in the United States, China, Canada, and South Korea recorded between 11 and 12 occurrences.

Because affiliation indicators may count repeated appearances across authors and documents, these values represent affiliation occurrences rather than confirmed numbers of unique publications. They nevertheless identify the institutions most frequently represented in the metadata of the analyzed literature.

Table 2. Leading affiliation occurrences and corresponding-author countries in the bibliometric dataset

Affiliation	Affiliation occurrences	Corresponding-author country	Documents	Documents (%)	SCP	MCP	MCP (%)
University of Oxford	99	USA	60	21.3	54	6	10.0
University of Pittsburgh	30	Italy	20	7.1	13	7	35.0
McPin Foundation	15	United Kingdom	20	7.1	18	2	10.0
Johns Hopkins University	14	China	13	4.6	13	0	0.0
Emory University School of Medicine	12	France	11	3.9	8	3	27.3
First Hospital/First Clinical Medical College of Shanxi Medical University	12	Poland	10	3.5	8	2	20.0
Indiana University	12	Australia	9	3.2	7	2	22.2

Affiliation	Affiliation occurrences	Corresponding-author country	Documents	Documents (%)	SCP	MCP	MCP (%)
School of Medicine							
University Health Network	12	South Korea	9	3.2	7	2	22.2
Yonsei University College of Medicine	12	Canada	8	2.8	6	2	25.0
Baylor College of Medicine	11	Netherlands	8	2.8	4	4	50.0

Note: SCP = single-country publications; MCP = multiple-country publications. Affiliation occurrences represent the frequency with which affiliations appeared in the bibliographic records and should not necessarily be interpreted as unique documents.

Based on corresponding-author countries, the United States led with 60 documents, representing 21.3% of the dataset. Of these, 54 were single-country publications and six were multiple-country publications, producing an MCP rate of 10.0%. Italy and the United Kingdom each contributed 20 corresponding-author documents, although their collaboration profiles differed. Italy recorded an MCP rate of 35.0%, compared with 10.0% for the United Kingdom.

China recorded 13 corresponding-author documents, all of which were single-country publications. France, Poland, Australia, South Korea, Canada, and the Netherlands showed varying degrees of international collaboration. The Netherlands recorded the highest MCP proportion among the countries listed, with four of its eight documents involving international co-authorship. Table 2 therefore shows that national research productivity and international collaboration did not necessarily follow the same pattern.

Author-Country Occurrences and Citation Impact

Table 3 distinguishes between author-country occurrences and country-level citation impact. The left panel reports the frequency with which countries appeared in authors' affiliation records. These frequencies may exceed the total number of documents because one publication can include several authors, affiliations, and countries. They should therefore not be interpreted as counts of unique articles.

Table 3. Author-country occurrences and citation impact by country

Country	Author-country occurrences	Country	Total citations	Average citations per document
USA	437	USA	1,620	27.00
United Kingdom	209	South Korea	499	55.40
Italy	107	Netherlands	493	61.60
China	93	France	479	43.50
Canada	70	United Kingdom	449	22.40
Poland	66	Canada	412	51.50
South Korea	64	Italy	354	17.70
France	52	Australia	322	35.80
Iran	42	Poland	301	30.10
Netherlands	38	Lithuania	170	85.00

The United States recorded the highest number of author-country occurrences, with 437, followed by the United Kingdom with 209, Italy with 107, and China with 93. Canada, Poland, South Korea, France, Iran, and the Netherlands also appeared frequently in authors' affiliation records. These findings confirm the concentration of research activity in North America, Europe, and parts of Asia.

The right panel of Table 3 summarizes country-level citation impact. The United States received the highest total number of citations, with 1,620, and an average of 27.00 citations per document. South Korea and the Netherlands recorded lower overall production frequencies but relatively high average citation values of 55.40 and 61.60, respectively. France and Canada also achieved comparatively high citation averages of 43.50 and 51.50.

Lithuania recorded the highest average citation value in the table, at 85.00 citations per document. However, country-level averages based on a small number of publications can be strongly influenced by one or two highly cited documents. Such values should therefore be interpreted together with publication volume and total citation counts.

Overall, Table 3 indicates that research volume and citation impact were not directly proportional. Countries with fewer contributions sometimes achieved high average citation values, whereas some highly productive countries recorded more moderate citation averages.

Most Globally Cited Documents

Table 4 lists the most globally cited documents in the dataset. Morina et al. (2015) ranked first in total citations, with 323 citations, 32.30 citations per year, and a normalized citation score of 5.04. Dascal et al. (2017) ranked second in total citations, with 280 citations, and recorded the highest normalized citation score in the table, at 6.61.

Table 4. Most globally cited documents and their citation impact

Document	DOI	Total citations	Citations per year	Normalized TC
Morina N, 2015, *Behaviour Research and Therapy* (Morina et al., 2015)	10.1016/j.brat.2015.08.010	323	32.30	5.04
Dascal J, 2017, *Innovations in Clinical Neuroscience*	—	280	35.00	6.61
Park MJ, 2019, *Frontiers in Psychiatry* (Park et al., 2019)	10.3389/fpsyt.2019.00505	238	39.67	5.08
Klinger E, 2005, *CyberPsychology & Behavior* (Klinger et al., 2005)	10.1089/cpb.2005.8.76	238	11.90	3.10
Harris SR, 2002, *CyberPsychology & Behavior* (Harris et al., 2002)	10.1089/109493102321018187	236	10.26	3.07
Gregg L, 2007, *Social Psychiatry and Psychiatric Epidemiology* (Gregg & Tarrier, 2007)	10.1007/s00127-007-0173-4	226	12.56	3.66

Document	DOI	Total citations	Citations per year	Normalized TC
Appel L, 2020, *Frontiers in Medicine* (Appel et al., 2020)	10.3389/fmed.2019.00329	158	31.60	3.94
Hoffman HG, 2004, *Scientific American* (Hoffman, 2004)	10.1038/scientificamerican0804-58	154	7.33	1.90
Emmelkamp PMG, 2021, *Annual Review of Clinical Psychology* (Emmelkamp & Meyerbröker, 2021)	10.1146/annurev-clinpsy-081219-115923	147	36.75	6.56
Cieślik B, 2020, *Complementary Therapies in Medicine* (Cieślik et al., 2020)	10.1016/j.ctim.2020.102480	142	28.40	3.54

Note: Normalized TC represents citation impact adjusted relative to other publications from the same publication year.

Park et al. (2019) received 238 total citations and recorded the highest annual citation rate, at 39.67 citations per year. Klinger et al. (2005) and Harris et al. (2002) received 238 and 236 citations, respectively, demonstrating the continuing influence of earlier work on virtual reality-based treatment for anxiety and related psychological conditions. Gregg and Tarrier (2007) also remained highly influential, with 226 total citations.

More recent publications showed strong citation performance after adjustment for their shorter citation windows. Appel et al. (2020) received 31.60 citations per year, while Emmelkamp and Meyerbröker (2021) received 36.75 citations per year and achieved a normalized citation score of 6.56. Cieślik et al. (2020) also showed substantial recent influence, with 142 total citations and 28.40 citations per year.

The citation patterns in Table 4 indicate that the intellectual foundation of the field has been shaped predominantly by studies and reviews concerning virtual reality therapy, exposure-based interventions, psychiatric applications, and the clinical feasibility of immersive technologies. The strong representation of VR-focused publications also shows that VR was more established in the citation structure of the dataset than AR- and AI-based therapeutic research.

The reasons for the high citation performance of individual documents cannot be determined directly from citation counts alone. Nevertheless, their publication timing, methodological relevance, clinical applicability, and interdisciplinary reach may have contributed to their visibility across psychology, psychiatry, neuroscience, and digital health research.

Keyword Co-Occurrence and Thematic Structure

Figure 4 presents the co-occurrence network of frequently associated terms and identifies four principal thematic clusters. Node size reflects the relative prominence of individual terms, while connections indicate their co-occurrence within the bibliographic metadata. Because several terms, including “human,” “article,” “female,” and “adult,” resemble database indexing descriptors, the network should be interpreted as a map of indexed concepts rather than a direct classification of clinical study designs.

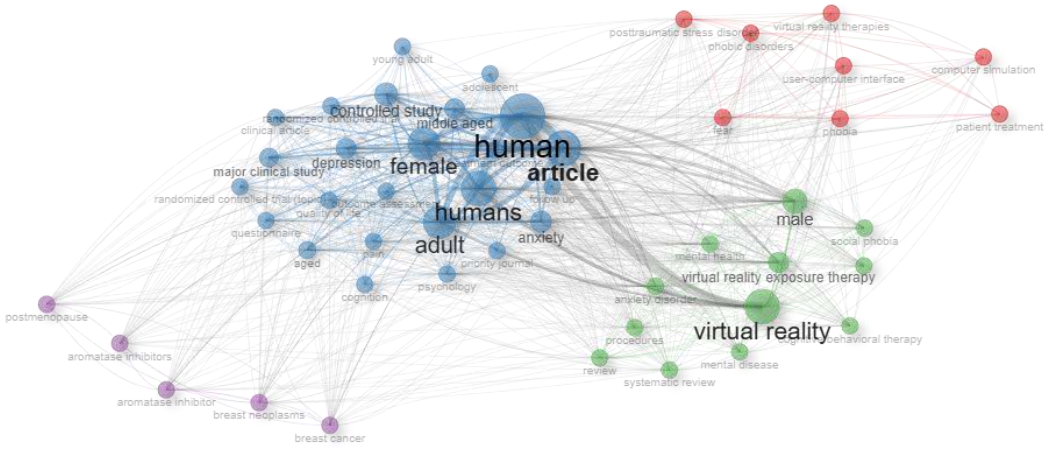

Figure 4. Co-occurrence network of key terms and thematic clusters in VR-, AR-, and AI-based mental health interventions.

Cluster 1 centers on mental health conditions commonly addressed through exposure-based interventions, including posttraumatic stress disorder, phobia, anxiety, panic, and related psychological responses. The prominence and connectivity of "phobia" and "posttraumatic stress disorder" demonstrate the central position of anxiety- and trauma-related conditions in the literature.

Cluster 2 includes broad population and outcome-related descriptors, such as "human," "female," "adult," "treatment outcome," and "quality of life." These terms indicate that the literature frequently considered participant characteristics and clinical or quality-of-life outcomes. However, their presence does not independently establish the methodological rigor or clinical effectiveness of the underlying studies.

Cluster 3 focuses on therapeutic approaches, including "virtual reality," "virtual reality exposure therapy," "cognitive behavioral therapy," "anxiety disorder," and "systematic review." This cluster demonstrates the strong association between immersive virtual environments, exposure-based treatment, and cognitive behavioral approaches. It also confirms that VR-related terminology was substantially more prominent than explicit AR- or AI-related terminology in the co-occurrence network.

Cluster 4 contains terms associated with breast cancer, aromatase inhibitors, and postmenopausal populations. This secondary cluster may reflect overlap between technology-assisted interventions, psychological well-being, treatment-related symptoms, and quality-of-life research in oncology populations. Its presence should be interpreted cautiously because it may also reflect the breadth of the search strategy or indexing practices rather than a distinct core domain of VR-, AR-, or AI-based mental health treatment.

Overall, Figure 4 shows that the thematic structure of the dataset was dominated by VR-based exposure therapy for phobias, anxiety, and posttraumatic stress disorder. AR and AI were included in the broader dataset but were less visible as central terms in the mapped network.

Evolution of Research Topics

Figure 5 illustrates the chronological development of prominent research topics across the study period. During the late 1990s and early 2000s, frequently occurring terms included "computer graphics," "desensitization, psychologic," and "computer

simulation." These terms reflect the technical and conceptual foundations from which computer-assisted and immersive therapeutic interventions developed.

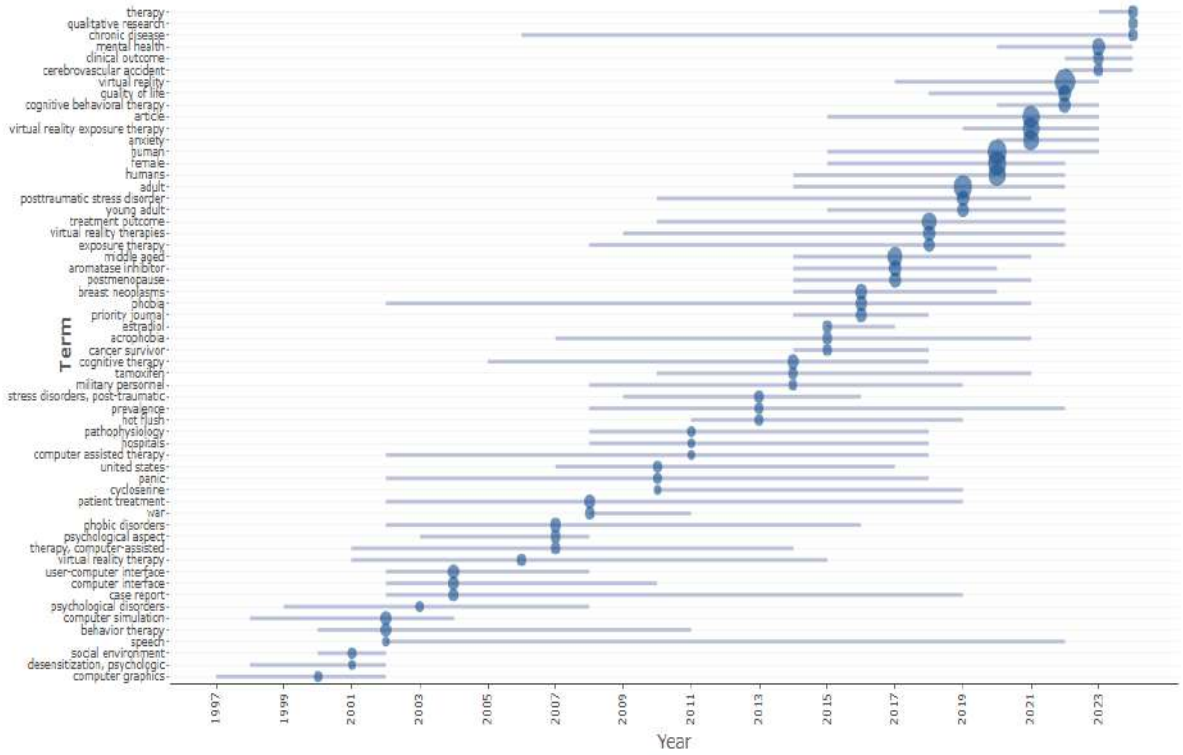

Figure 5. Trending topics in research on VR-, AR-, and AI-based mental health interventions, 1996–2024.

Between approximately 2002 and 2011, the literature increasingly emphasized "behavior therapy," "user-computer interface," and "computer-assisted therapy." This shift indicates growing attention to the practical interaction between users and therapeutic technologies rather than to technical development alone.

From the mid-2000s onward, "virtual reality therapy," "phobic disorders," "stress disorders, post-traumatic," "panic," and "exposure therapy" became increasingly prominent. These trends demonstrate the consolidation of VR as a therapeutic modality for anxiety-, trauma-, and fear-related conditions.

After 2010, outcome-oriented and population-related topics became more visible. Terms such as "quality of life," "treatment outcome," and "cognitive therapy" indicate increased attention to clinical consequences and patient-centered outcomes. From approximately 2018 onward, "virtual reality exposure therapy," "cognitive behavioral therapy," and "mental health" became prominent, reflecting the integration of immersive technologies into established psychological treatment frameworks.

More recent topics between 2020 and 2024 included "virtual reality," "clinical outcome," "mental health," "chronic disease," "qualitative research," and "therapy." These trends suggest that the field has expanded from technical experimentation toward clinical implementation, user experience, and broader patient-centered evaluation. Nevertheless, Figure 5 again demonstrates that VR-related terminology was more prominent than explicit AR- and AI-related terminology. Therefore, the topic evolution should be interpreted as reflecting a dataset in which VR formed the most mature and visible technological domain.

International Collaboration Patterns

Figure 6 maps international co-authorship links among countries represented in the dataset. The network was geographically concentrated in North America and Europe, with additional links involving countries in Asia, the Middle East, and Africa. This pattern is consistent with the overall international co-authorship rate of 19.15%, indicating the presence of cross-border collaboration but also showing that most documents did not involve authors from multiple countries.

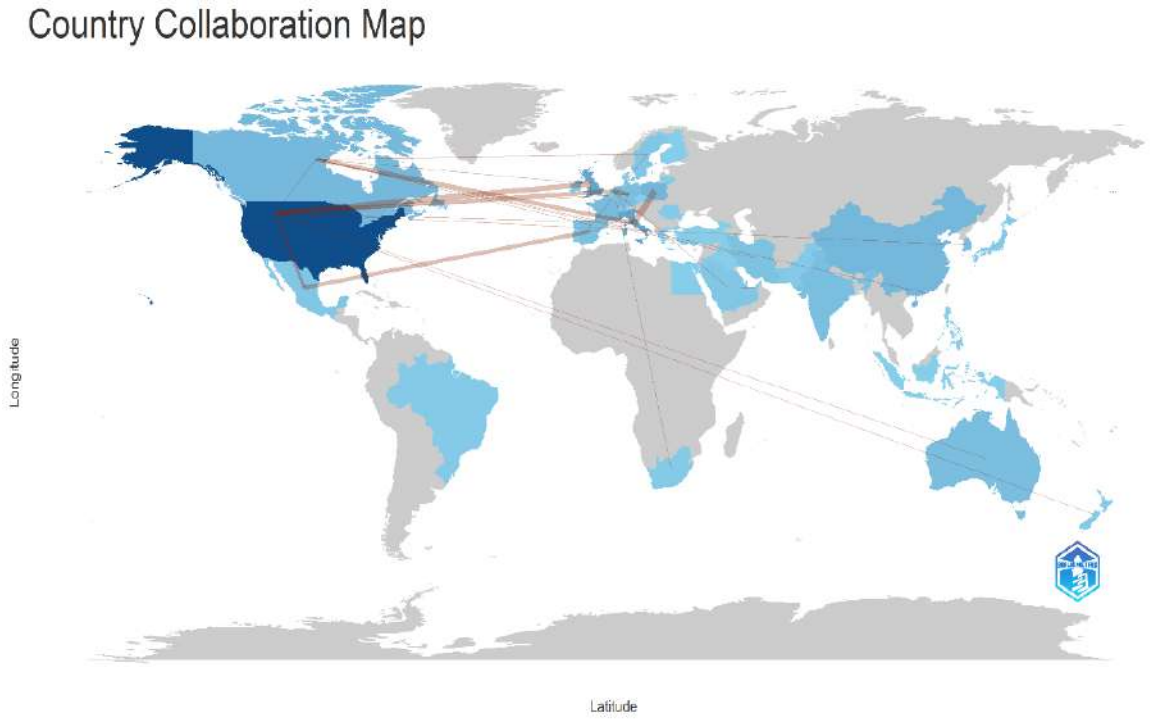

Figure 6. International collaboration map of research on VR-, AR-, and AI-based mental health interventions.

The United States occupied a central position in the collaboration network and maintained links with the United Kingdom, Mexico, and the Netherlands. The United States–United Kingdom link involved four collaborations, while the United States recorded three collaborations each with Mexico and the Netherlands. These connections show that the United States functioned as an important collaboration hub in the analyzed literature.

The United Kingdom also collaborated with countries including Canada and Spain. Italy showed several intra-European links, most notably with Poland, with six recorded collaborations, as well as with the Netherlands and Spain. These patterns indicate that European collaboration was often organized through regional partnerships.

Canada maintained links with the United States and also collaborated with Hong Kong, Iran, and Sweden, demonstrating connections across North America, Asia, the Middle East, and Europe. Emerging links involving Saudi Arabia, the United Arab Emirates, South Africa, and the Netherlands indicate participation from regions that otherwise remained comparatively underrepresented in overall research production.

Despite these international connections, Figure 6 shows that collaboration remained concentrated among established research systems in North America and Europe. Representation from Africa and South America was limited, and several regions appeared only through isolated partnerships. The collaboration map therefore

identifies an emerging but geographically uneven international network rather than a uniformly distributed global research structure.

Discussion

Growth and Maturation of the Research Field

The publication pattern summarized in Figures 2 and 3 indicates that technology-assisted mental health research has moved from an early exploratory phase toward a more established interdisciplinary field. The sustained annual growth reflects increasing interest in integrating immersive and computational technologies into psychological and psychiatric care. However, the lower citation averages for recent publication years are more plausibly explained by citation lag than by reduced scholarly relevance. This temporal effect is particularly important when interpreting publications from 2023 and the partial 2024 publication year.

The relatively recent mean age of the literature also suggests that the field is evolving alongside rapid changes in hardware, software, and digital health infrastructure. This pattern is consistent with previous reviews showing that improvements in affordability, usability, and immersion have expanded the clinical application of VR beyond experimental laboratory settings (Emmelkamp & Meyerbröker, 2021; Lindner, 2021; Riva et al., 2019). At the same time, rapid technological development creates challenges for evidence synthesis because devices and intervention platforms may become outdated before long-term clinical outcomes are established.

Dominance of Virtual Reality in the Knowledge Structure

Although this study jointly examined VR, AR, and AI, the source rankings, citation structure, and thematic visualizations show that VR constitutes the most mature component of the field. Table 4 is dominated by publications examining virtual reality exposure therapy, psychiatric applications of immersive environments, and the generalization of therapeutic gains to real-world settings. Foundational studies by Klinger et al. (2005), Gregg and Tarrier (2007), and Morina et al. (2015) helped establish VR as a clinically relevant approach for anxiety and phobia treatment, while later reviews consolidated evidence across psychiatric conditions (Cieślik et al., 2020; Emmelkamp & Meyerbröker, 2021; Park et al., 2019).

This dominance is also visible in Figures 4 and 5, where virtual reality, virtual reality exposure therapy, phobia, anxiety, posttraumatic stress disorder, and cognitive behavioral therapy form the central thematic structure. The pattern is clinically plausible because VR allows therapists to control the intensity, duration, and repetition of exposure while reducing the logistical barriers associated with reproducing real-world feared situations. Previous studies have similarly shown that VR-based exposure can produce outcomes comparable to conventional exposure approaches for selected anxiety disorders while increasing treatment acceptability and control (Emmelkamp et al., 2020; Morina et al., 2015).

By contrast, explicit AR- and AI-related terms were less prominent in the keyword network and citation rankings. This imbalance should not be interpreted as evidence that AR and AI lack therapeutic relevance. Instead, it may reflect differences in the maturity of the evidence base, terminology used by authors, and database indexing practices. AR research remains comparatively limited and has often focused on narrowly defined applications, such as exposure therapy for specific phobias (Albakri et al., 2022; Jurcik et al., 2024; Toffolo et al., 2022). AI research, meanwhile, is

frequently indexed under terms such as machine learning, chatbot, natural language processing, predictive modeling, or digital mental health rather than "AI therapy," which may have reduced its visibility within the present search framework (Khawaja & Bélisle-Pipon, 2023; Lee et al., 2018; Pavlopoulos et al., 2024).

Thematic Concentration on Anxiety- and Trauma-Related Conditions

The thematic clusters in Figure 4 indicate that anxiety disorders, phobias, and posttraumatic stress disorder remain the principal clinical contexts in which immersive technologies have been studied. This concentration reflects the compatibility between exposure-based treatment and programmable virtual environments. VR enables clinicians to reproduce feared stimuli in a controlled manner, adjust exposure intensity, and repeat therapeutic scenarios without relying on unpredictable real-world conditions. These characteristics help explain why exposure therapy and cognitive behavioral therapy are closely connected within the network.

The topic evolution in Figure 5 further suggests that the field has progressed from technical experimentation involving computer graphics and simulation toward clinically oriented concerns such as treatment outcomes, quality of life, cognitive behavioral therapy, and mental health. This transition is consistent with broader developments in VR-based psychological treatment, where research attention has shifted from demonstrating technological feasibility to evaluating clinical usefulness and patient outcomes (Emmelkamp et al., 2020; Lindner, 2021).

Nevertheless, the dominance of anxiety- and trauma-related themes also identifies a limitation in therapeutic diversity. Bipolar disorder, schizophrenia-spectrum disorders, severe depression, substance-use disorders, and culturally specific presentations of psychological distress were less visible in the mapped structure. Although VR has been examined across a broader range of psychiatric disorders, the evidence remains uneven, and many applications have not reached the same level of maturity as exposure-based treatment for anxiety and phobias (Cieślik et al., 2020; Park et al., 2019).

Interpretation of Indexed and Secondary Thematic Terms

Several prominent terms in Figure 4, including "human," "female," "adult," "article," and "review," appear to reflect database indexing conventions rather than substantive research themes. Their presence should therefore not be used to infer the predominance of particular study designs or to conclude that the literature lacks clinical trials. Determining the proportion of randomized controlled trials, observational studies, reviews, and feasibility studies would require document-level methodological classification beyond the present co-occurrence analysis.

The separate cluster containing breast cancer, aromatase inhibitors, postmenopausal populations, and quality of life also requires cautious interpretation. Its presence is consistent with the appearance of Breast Cancer Research and Treatment among the sources listed in Table 1. This pattern may reflect research examining psychological distress, treatment-related symptoms, or quality-of-life outcomes in oncology populations. Technology-enhanced interventions are increasingly used in broader medical contexts, including support for patients with chronic illness or physical impairment (Appel et al., 2020). However, the cluster may also indicate that the search strategy captured studies in which mental health was a

secondary rather than primary therapeutic outcome. Document-level validation would be necessary to determine the exact contribution of these publications.

Interdisciplinary Publication and Citation Structure

Table 1 demonstrates that the field is distributed across journals specializing in cyberpsychology, health informatics, psychiatry, psychology, serious games, and clinical research. The prominence of Studies in Health Technology and Informatics and Cyberpsychology and Behavior reflects the historical role of technology-focused outlets in establishing the scientific foundations of immersive therapy. More recent journals, including Frontiers in Psychiatry, JMIR Mental Health, Journal of Medical Internet Research, and JMIR Serious Games, show that the field has increasingly become integrated into mainstream digital health and psychiatric research.

The contrast between publication productivity and citation impact is also important. A source may publish many documents without necessarily achieving the highest citation influence, while journals with fewer publications may contain highly influential contributions. The high citation performance of the documents in Table 4 indicates that conceptual reviews, early clinical studies, and meta-analyses have played a particularly important role in shaping the field. For example, Morina et al. (2015) addressed whether gains from virtual exposure transfer to real-life behavior, while Emmelkamp and Meyerbröker (2021) synthesized the clinical development of VR therapy. Their influence likely reflects their relevance to both research design and clinical implementation.

Citation prominence should nevertheless be interpreted as scholarly visibility rather than direct evidence of methodological quality or treatment effectiveness. Older publications have had more time to accumulate citations, whereas normalized citation indicators and citations per year provide a more balanced view of recent influence. The strong normalized performance of several newer publications suggests that interest in clinically applicable immersive interventions remains high.

Geographic Concentration and Collaboration Inequality

The geographic patterns in Tables 2 and 3 indicate that research leadership remains concentrated in the United States and Europe, with additional high-impact contributions from countries such as South Korea, Canada, and the Netherlands. The distinction between productivity and influence is noteworthy: countries with fewer author-country occurrences sometimes achieved higher average citation values, suggesting that research impact is not determined solely by publication volume. However, average citation values for countries with relatively few documents may be disproportionately affected by a small number of highly cited studies and should therefore be interpreted cautiously.

Figure 6 shows that international collaboration has developed through several prominent North American and European partnerships, but the network remains geographically uneven. The international co-authorship rate of 19.15% indicates that most publications were produced without cross-country collaboration. This concentration may limit the cultural and contextual generalizability of the resulting interventions, particularly when technologies are designed and evaluated in well-resourced clinical and academic settings.

The limited representation of Africa, South America, and many low- and middle-income countries is particularly important because access, affordability, digital literacy, infrastructure, language, and attitudes toward mental health treatment differ

substantially across settings. Previous research has shown that the adoption and effectiveness of digital psychological interventions depend on contextual factors, user experience, and access to technological support (Alruwaili et al., 2023; Castro et al., 2023; Vailati Riboni et al., 2020). More geographically inclusive research is therefore necessary not only to address publication inequality but also to determine whether VR-, AR-, and AI-based interventions remain acceptable and effective across diverse populations.

Clinical Interpretation and Evidence Gaps

The bibliometric expansion identified in this study demonstrates increasing scientific attention, but publication growth should not be equated with established clinical effectiveness. The analyzed patterns identify influential themes, sources, and collaborations; they do not directly evaluate intervention effect sizes, adverse events, treatment adherence, or long-term safety. Evidence from previous systematic reviews indicates that technology-assisted interventions can benefit selected populations, but efficacy varies by condition, intervention design, level of therapist involvement, and patient characteristics (Greenwood et al., 2022; Vailati Riboni et al., 2020).

The expanding role of AI introduces additional considerations. AI-powered chatbots, predictive systems, and personalized treatment tools may improve accessibility and continuous support, but concerns remain regarding privacy, transparency, empathy, clinical accountability, and the risks of providing automated support without adequate professional oversight (Espejo et al., 2023; Khawaja & Bélisle-Pipon, 2023; Terra et al., 2023). Because AI was less visible than VR in the present thematic analysis, future bibliometric work should use broader AI-related terminology to determine whether its apparent underrepresentation reflects a genuine evidence gap or limitations in the search strategy.

Similarly, AR appears promising for contextual exposure because it combines virtual stimuli with real-world surroundings, but its evidence base remains smaller and more condition-specific than that of VR (Albakri et al., 2022; Jurcik et al., 2024). Direct comparisons among VR, AR, AI-assisted therapy, face-to-face treatment, and other digital interventions are therefore needed to clarify the circumstances in which each technology provides a meaningful clinical advantage.

Implications

Because the bibliometric dataset covered publications indexed through 2024, studies published in 2025 are cited in this section only to contextualize recent technological, clinical, and regulatory developments and were not included in the bibliometric analysis.

Clinical and Technological Implications

The thematic concentration shown in Figures 4 and 5 indicates that VR and AR are especially compatible with structured, exposure-based interventions for anxiety, phobias, posttraumatic stress disorder, and related conditions. Their capacity to control stimulus intensity, duration, and repetition may support individualized treatment delivery. Integration with machine-learning techniques may further enable adaptive feedback and personalization (Leong, 2025; Singha & Singha, 2024; Halkiopoulos & Gkintoni, 2025; Ioannidou et al., 2025).

AI extends this therapeutic landscape through symptom screening, pattern detection, risk assessment, treatment personalization, and continuous monitoring. Machine-learning systems can analyze behavioral and clinical data associated with

depression, anxiety, and related conditions, while conversational agents may provide psychoeducation, structured self-help, and between-session support (Ioannidou et al., 2025; Mittal et al., 2023; Thirupathi et al., 2024; Jermsittiparsert & Marzo, 2024; Punia et al., 2025; Malouin-Lachance et al., 2025). These applications may improve continuity and accessibility, but their clinical value depends on appropriate human oversight, particularly for users with severe symptoms or crisis risk.

Implementation and Economic Implications

The transition from research to routine care is influenced by affordability, infrastructure, workforce readiness, and compatibility with existing clinical workflows. VR implementation may require investment in headsets, computers, software, maintenance, staff training, infection-control procedures, and technical support (Farra et al., 2019; Felnhofer et al., 2025; Glegg & Levac, 2018). Although reusable systems may reduce recurring costs over time, high initial expenditure can remain a barrier, especially in under-resourced services.

Similarly, cloud-based AI platforms may lower local computing requirements but increase dependence on reliable connectivity, secure data transmission, and cybersecurity. Economic feasibility therefore extends beyond equipment prices and includes organizational capacity, staff time, maintenance, and data-protection requirements (Iqbal et al., 2024).

Equity and Global Collaboration Implications

The geographic concentration identified in Tables 2 and 3 and Figure 6 suggests that the evidence base has been shaped predominantly by high-resource research systems. This pattern may restrict the cultural and contextual generalizability of interventions because language, digital literacy, infrastructure, affordability, and perceptions of mental health differ across settings. Limited participation from low- and middle-income countries also raises concerns about whether emerging technologies are being developed around the needs of globally diverse populations.

The observed collaboration structure therefore has implications beyond publication inequality. It affects whose clinical priorities are represented, which populations are studied, and whether interventions can be transferred responsibly across health systems. Capacity-building partnerships and context-sensitive implementation models are particularly relevant to addressing these imbalances (Glegg & Levac, 2018; Felnhofer et al., 2025; Iqbal et al., 2024).

Ethical and Regulatory Implications

AI-enabled mental health interventions raise concerns regarding privacy, informed consent, data security, algorithmic bias, transparency, and accountability (Thirupathi et al., 2024; Jermsittiparsert & Marzo, 2024; Malik & Surbhi, 2024). These risks are especially important when systems process sensitive psychological information or are used by children, individuals with severe mental illness, or other vulnerable groups.

Human-centered design and professional oversight remain essential because automated systems cannot independently assume therapeutic responsibility (Abilash et al., 2025). Emerging regulatory frameworks, including the European Union's AI governance approach, provide a useful foundation, but mental health applications require additional safeguards for clinician review, crisis escalation, data reuse, and accountability for automated decisions (Punia et al., 2025; Malouin-Lachance et al., 2025; Carneiro & Gomes, 2025).

CONCLUSIONS

This bibliometric study mapped the development, citation influence, thematic structure, and collaboration patterns of research on virtual reality (VR)-, augmented reality (AR)-, and artificial intelligence (AI)-based mental health interventions. The analysis included 282 Scopus-indexed documents published between 1996 and 2024 and identified an annual growth rate of 14.47%. Because the data were retrieved on November 7, 2024, the publication count for 2024 represents partial-year coverage. The source, citation, and keyword analyses indicate that VR—particularly virtual reality exposure therapy for posttraumatic stress disorder, anxiety, and phobias—constitutes the most mature and influential technological domain, whereas AR- and AI-based therapeutic applications remain less prominent in the mapped literature.

Research activity was concentrated primarily in the United States, the United Kingdom, Italy, and other high-resource countries, although the Netherlands, South Korea, and Canada achieved comparatively high citation impact. The limited representation of many low- and middle-income regions and the international co-authorship rate of 19.15% demonstrate that the field remains geographically uneven. By examining VR, AR, and AI within a single bibliometric framework, this study identifies imbalances in technological maturity, therapeutic focus, and global research participation. Future progress requires stronger clinical validation, broader investigation of mental health conditions beyond anxiety- and trauma-related disorders, culturally and contextually adapted interventions, transparent ethical and data-governance frameworks, and equitable international partnerships. Addressing these priorities will help ensure that technology-assisted mental health interventions develop into clinically meaningful, accessible, and responsible components of mental health care.

RECOMMENDATIONS

Because the bibliometric dataset covered publications indexed through 2024, studies published in 2025 are cited only to contextualize emerging developments and were not included in the analysis.

Future research should broaden the clinical scope of VR-, AR-, and AI-based interventions beyond anxiety, phobias, and posttraumatic stress disorder. Priority areas include major depression, bipolar disorder, schizophrenia-spectrum disorders, substance-use disorders, and culturally specific manifestations of psychological distress. Researchers should also compare these technologies with face-to-face psychotherapy, telehealth, and conventional digital interventions to determine when they provide meaningful clinical advantages.

Stronger clinical validation is required through adequately powered randomized controlled trials, multicenter studies, mixed-methods designs, and longitudinal follow-up. Evaluations should assess symptom change, functional recovery, adherence, adverse events, therapeutic alliance, user satisfaction, and long-term safety. Standardized reporting of intervention components, including immersion, personalization, therapist involvement, and automated feedback, would improve comparability across studies.

Interventions should be culturally adapted and accessible to users with different languages, socioeconomic backgrounds, disabilities, digital literacy levels, and infrastructure constraints. Patients, caregivers, clinicians, and community

representatives should participate in development and evaluation. Studies should also address cybersickness, hardware usability, cognitive load, and clinician burden.

Economic evaluations should consider hardware, software, maintenance, staff training, cybersecurity, technical support, and workflow integration. Shared headset pools, mobile VR units, and centralized technical support may improve feasibility, although affordability must not compromise safety or clinical quality (Farra et al., 2019; Iqbal et al., 2024).

AI-based interventions require safeguards for privacy, informed consent, algorithmic transparency, accountability, and human oversight. Regulatory frameworks should distinguish wellness applications from tools intended to support clinical decisions or treat mental disorders (Punia et al., 2025; Malouin-Lachance et al., 2025; Carneiro & Gomes, 2025).

Finally, international collaboration should strengthen meaningful participation from low- and middle-income countries through shared protocols, reciprocal training, equitable authorship, and sustained capacity building (Glegg & Levac, 2018; Felnhofer et al., 2025). Future bibliometric studies should integrate multiple databases and multilingual sources while reporting complete search strategies, analytical parameters, and reproducible workflows.

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Conflict of Interest Statement

The authors declare that they have no financial, professional, or personal conflicts of interest that could have influenced the research, analysis, or preparation of this manuscript.

Data Availability

The bibliographic data analyzed in this study were retrieved from the Scopus database on November 7, 2024. The processed data and supporting analytical materials are available from the corresponding author upon reasonable request, subject to Scopus licensing and data-use restrictions.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
SA Toha Md Saky	✓	✓			✓			✓	✓		✓			
M Zakki Azani		✓		✓		✓	✓			✓				
Md Nurul Islam				✓		✓				✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

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