

A Systematic Bibliometric Analysis of Virtual Reality Research in Mental Health: Trends, Hotspots, and Future Directions.

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Abstract

Background: With the increasing maturity of the technology and the gradual reduction of costs, virtual reality is playing an increasingly important role in clinical therapy.

Objective: This study aims to analyze the current status and developmental trends of virtual reality (VR) research in mental health.

Methods: We analyzed 1,116 publications spanning from 1994 to 2022, sourced from the Web of Science. Our analysis included visualization of authorship, institutional affiliations, countries, cited literature, and key terms.

Results: Harvard Medical School emerged as the leading institution in terms of publication volume in this field. Giuseppe Riva was identified as the most prolific author in VR mental health research. The American Journal of Psychiatry was distinguished by its high centrality and impact factor (IF = 17.7, 2022). Recent trends, indicated by emerging keywords and citation bursts, point to growing research interests in areas such as geriatric mental health, environmental influences, and pain management. The predominant research hotspots over the past two decades have been schizophrenia, anxiety, and post-traumatic stress disorder, with emerging frontiers in the study of environmental factors and pain.

Conclusions: This study systematically outlines the evolution, current landscape, and potential future directions of VR research in mental health, offering valuable insights for researchers in the field.

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Original Manuscript

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Background

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Harvard Medical School emerged as the leading institution in terms of publication volume in this field. Giuseppe Riva was identified as the most prolific author in VR mental health research. The American Journal of Psychiatry was distinguished by its high centrality and impact factor. Recent trends, indicated by emerging keywords and citation bursts, point to growing research interests in areas such as geriatric mental health, environmental influences, and pain management. The predominant research hotspots over the past two decades have been schizophrenia, anxiety, and post-traumatic stress disorder, with emerging frontiers in the study of environmental factors and pain.

Conclusion:

This analysis underscores VR's growing role in mental health research, highlighting transitions from disorder-specific interventions to contextualized, patient-centered approaches. Future directions should prioritize interdisciplinary collaboration and technological integration to address unmet clinical needs.

Keywords: mental health; virtual reality; bibliometric; visualization

Introduction

Virtual reality (VR), an immersive human-computer interaction technology emerging in the 1990s, utilizes head-mounted displays and motion controllers to create simulated environments [1, 2]. With the maturation and cost reduction of digital technology, VR has gained traction in clinical settings [3]. In therapeutic applications, VR technology offers a high degree of control over treatment experiences, thereby enhancing patients' subjective sense of security [4]. Additionally, VR facilitates the creation of personalized treatment atmospheres while reducing logistical and financial burdens associated with traditional treatment methods [5-7]. Such as in the case of VR-based Exposure Therapy (VRET) which provides more ecologically valid and safer alternatives to traditional exposure and in-vivo exposure therapy [8].

VR has been applied across diverse psychotherapeutic contexts [6, 9, 10], including phobia treatment [11] and cognitive reinforcement in mild cognitive impairment associated with Alzheimer's disease [12]. Avatar Therapy for schizophrenia further exemplifies VR's innovative

potential [13].

The relevance of VR for mental health care was particularly accentuated during the COVID-19 pandemic, a period marked by elevated global mortality, morbidity, and exacerbated psychological distress [14]. Compounding this issue, prevalence studies indicated that over half of American adolescents experienced depressive symptoms, with 37% reporting suicidal ideation [15]. Restrictions on in-person interventions during this crisis underscored the urgent need for alternative service delivery modalities, positioning VR as a promising tool for remote mental health support [16].

Bibliometrics, which was first introduced in the year 1969 [17], is widely recognized as an essential and powerful tool that facilitates both the quantitative and qualitative assessment of scientific research, encompassing a broad spectrum of fields and disciplines [18-21]. This methodology allows researchers to systematically analyze and interpret the vast amounts of literature produced in various domains, thereby providing valuable insights into the impact and evolution of scientific knowledge [22-24]. Among the tools available for bibliometric analysis, CiteSpace stands out as a prominent and highly regarded software application that specializes in visual bibliometric analysis. It offers robust support for conducting co-occurrence and cluster analyses of scholarly networks, enabling researchers to uncover patterns and relationships within the academic literature [25-28].

In this study, we utilize CiteSpace to perform the first comprehensive bibliometric review that is specifically centered on the applications of VR in the realm of mental health. This review aims to delineate the developmental trajectory of VR technologies in this field and to identify emerging trends that may shape future research and practice.

Methods

Document source

The primary data source for this study is the Web of Science (WOS), an academic citation indexing and search service provided by Thomson Reuters encompassing a broad spectrum of sources, including journals, conference papers, websites, patents, and chemical structures [29]. WOS offers detailed information such as author indexes and cited work indexes, which can be accessed as needed [30]. Impact factors and journal quartiles for this study were sourced from the Journal Citation Reports [31]. The results from WOS can be thoroughly analyzed, with citation reports presented in labeled bar charts. Additionally, the system allows for the definition of specific results, enabling researchers to view or exclude records as required [30].

Search strategy and exclusion criteria

In the literature retrieval process for this study, specific parameters were set. The search language was confined to English, and the database used was the WOS Core Collection, with document types limited to research papers and review articles. The search query was formulated as follows: TS=(mental health OR mental hygiene) AND TS=(virtual reality OR VR OR Educational Virtual Reality* OR Instructional Virtual Reality). To ensure comprehensive journal data coverage, the retrieval spanned from 1994 to 2022. Data collection from the WOS database was conducted on February 2, 2023. Subsequently, the retrieved literature from WOS was imported into CiteSpace for deduplication. This process resulted in a total of 1,116 papers, published between 1994 and 2022, being compiled as of February 2, 2023. For the analysis, we utilized CiteSpace 6.1.R6, a software renowned for its robust analytical capabilities in various fields. The basic settings of CiteSpace are: the period is 1985-2021, the time slice is 1 year, the term selection is "Title", "Abstract", "Author Keyword" and "Keyword Plus", and the number of objects in each time slice is set to 5, using the pathfinder algorithm.

Results

Analysis of Annual Publications

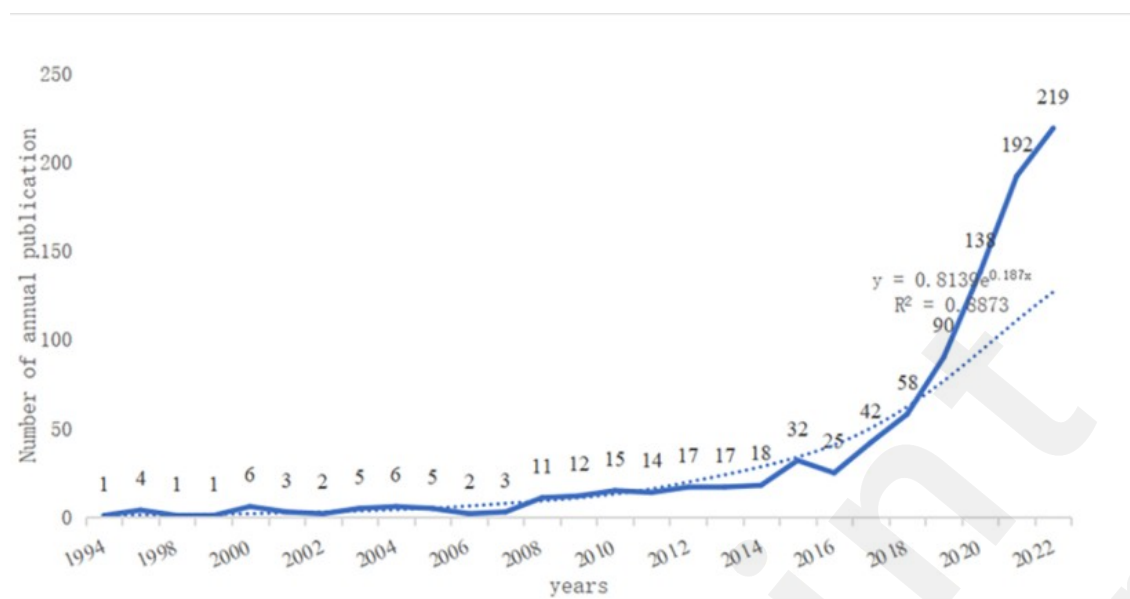


Figure 1. Annual publications in virtual reality for mental health.

An overall upward trend in publication numbers from 1994 to 2022 is illustrated in Figure 1. It is noteworthy that from 1994 to 2007, the annual publication count remained in single digits, implying that VR research in mental health did not attract significant attention during this period. However, there was a fluctuation in publication numbers post-2000, reaching a notable peak in 2015 when 32 papers were published within that year. Subsequently, despite a brief dip, there was a rapid increase, nearly doubling in the initial years. This pattern indicates that VR research in mental health exhibits substantial growth potential.

Analysis of countries

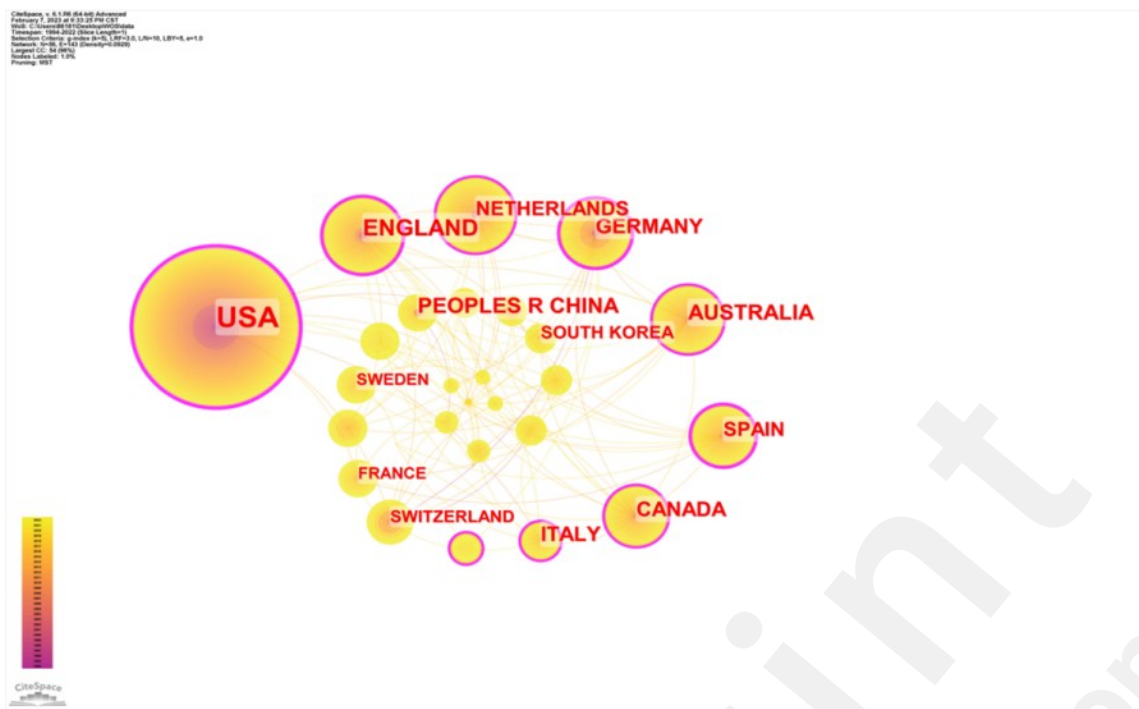


Figure 2. Analysis of countries. The area of the node is positively correlated with the frequency. In this co-citation knowledge map, the purple outer ring of the node indicates the higher betweenness centrality. The analysis includes 'N' representing the number of nodes and 'E' denoting the number of edges. Node size reflects the frequency of data references or occurrences, while the connecting lines illustrate the relationships between nodes, with line thickness indicating the strength of these connections.

A country collaboration network chart was generated using CiteSpace, detailed Figure 2. From the data, it can be concluded that the United States is in an absolute leading position in the application of VR in the field of mental health, with the highest number of contributions (362 articles), far surpassing the second place in the United Kingdom (92 articles). The highest centrality (0.52) indicates that the United States not only produces a lot of output, but also plays a role as a hub and bridge in the national cooperation network, and can aggregate research resources and achievements from other countries. European countries represented by the United Kingdom, Italy, and Germany have relatively high centrality and the number of articles, and have strong connectivity in transnational cooperation networks, which can promote the flow and sharing of knowledge. And the top ten countries are basically high-income economies (the United States, the United Kingdom, Australia, etc.) [32], which is consistent with the positive correlation between "scientific research

resources-output" common in bibliometrics.

Analysis of author and institution

Figure 3 presents an analysis featuring 201 nodes and 129 edges, with a network density of 0.0064. In this graphical representation, each node symbolizes an author or organization, while the lines connecting these nodes depict collaborative links. The frequency of connections between nodes correlates with the intensity of collaboration among authors and organizations. A network density of 0.0064, as observed in this study, suggests a relatively dispersed collaboration pattern. This indicates that within the scope of this research, interactions and cooperative endeavors among authors and organizations are not densely concentrated but rather spread out across the network.

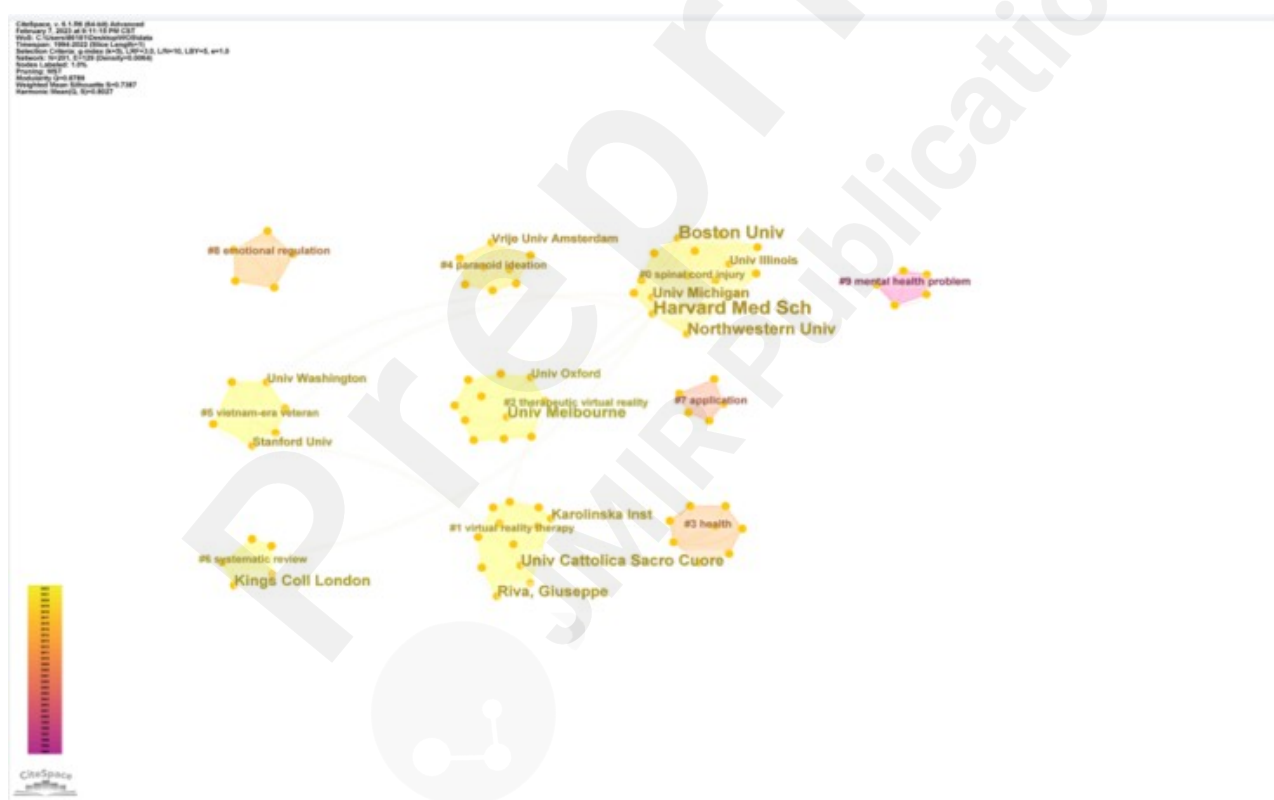


Figure 3. Analysis of author and institution.

Figure 3 provides an insightful cluster analysis of authors and institutions within the field of VR research in mental health. The analysis reveals the top ten largest clusters: #0 'spinal cord injury,' #1 'virtual reality therapy,' #2 'therapeutic virtual reality,' #3 'health,' #4 'paranoid ideation,' #5 'Vietnam-

era veteran,' #6 'systematic review,' #7 'application,' #8 'emotional regulation,' and #9 'mental health problem.' This clustering provides insight into the collaborative dynamics among authors and institutions and highlights their respective research focuses. Additionally, an assessment of the most active research institutions, as identified in Supplementary Table 1, shows Harvard Medical School, Boston University, and Northwestern University, all based in the United States, as the leading contributors. Author productivity in this research domain, detailed in Supplementary Table 2, identifies Giuseppe Riva from Italy as the leading author with 11 publications, followed by Per Carlbring from Sweden with 7 articles and Andrea Gaggioli from Italy with 5 articles.

Analysis of keyword co-occurrence and keyword clustering

An extensive overview of the primary keywords within the domain of VR research in mental health from 1994 to 2022 is presented in Figure 4(a) and Table 1. The most frequently occurring keywords during this period include 'VR,' 'depression,' 'mental health,' and 'quality of life.' A cluster analysis of these keywords led to the identification of six major clusters, which are prominently featured in Figure 1(b). These clusters encompass diverse areas such as 'multiple sclerosis,' 'posttraumatic stress disorder,' 'therapeutic VR,' 'VR relaxation,' 'controlled trial,' and 'systematic review.' Notably, 'posttraumatic stress disorder' emerges as the second-largest cluster, underscoring its significance as a key research focus in the field.

Table 1 Top 10 keywords in virtual reality for mental health.

Ranking	Count	Centrality	Keyword	Ranking	Count	Frequency	Keyword
1	402	0.55	virtual reality	1	402	0.55	virtual reality
2	86	0.24	depression	2	265	0.15	mental health
3	66	0.16	posttraumatic stress disorder	3	86	0.24	depression
4	265	0.15	mental health	4	81	0.15	quality of life

5	81	0.15	quality of life	5	78	0.14	health
6	78	0.14	health	6	72	0.05	intervention
7	71	0.13	exposure	7	71	0.13	exposure
8	35	0.13	therapy	8	67	0.12	therapy
9	67	0.12	care	9	66	0.16	anxiety
			anxiety				posttraumatic
							stress disorder

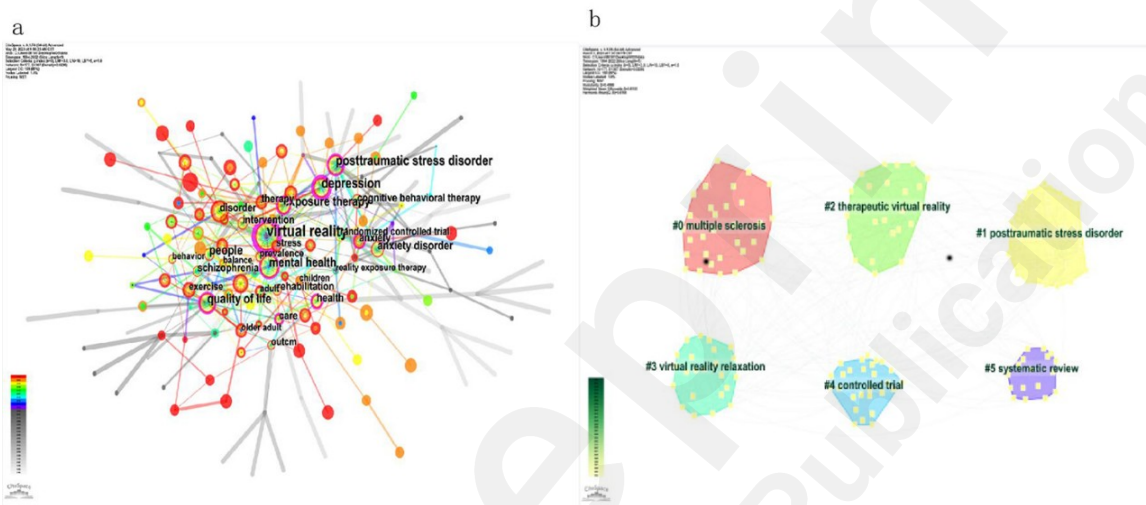


Figure 4. Keyword co-occurrence and keyword clustering. (a) Keyword co-occurrence on virtual reality for mental health. (b) Keyword clustering

Analysis of Keyword Timeline

Figure 5 provides a comprehensive analysis of the research focus with different clusters over various periods. Notably, the two most prominent clusters are Cluster #0, which is dedicated to multiple sclerosis, and Cluster #1, which revolves around posttraumatic stress disorder. This points to the prolonged research interest in post-traumatic stress disorder and therapeutic virtual reality over the span of the last two decades. Furthermore, of particular significance is the emergence of Cluster #5, which is primarily focused on systematic reviews and has gained recognition as the fifth significant cluster. This indicates a more recent area of research focus.

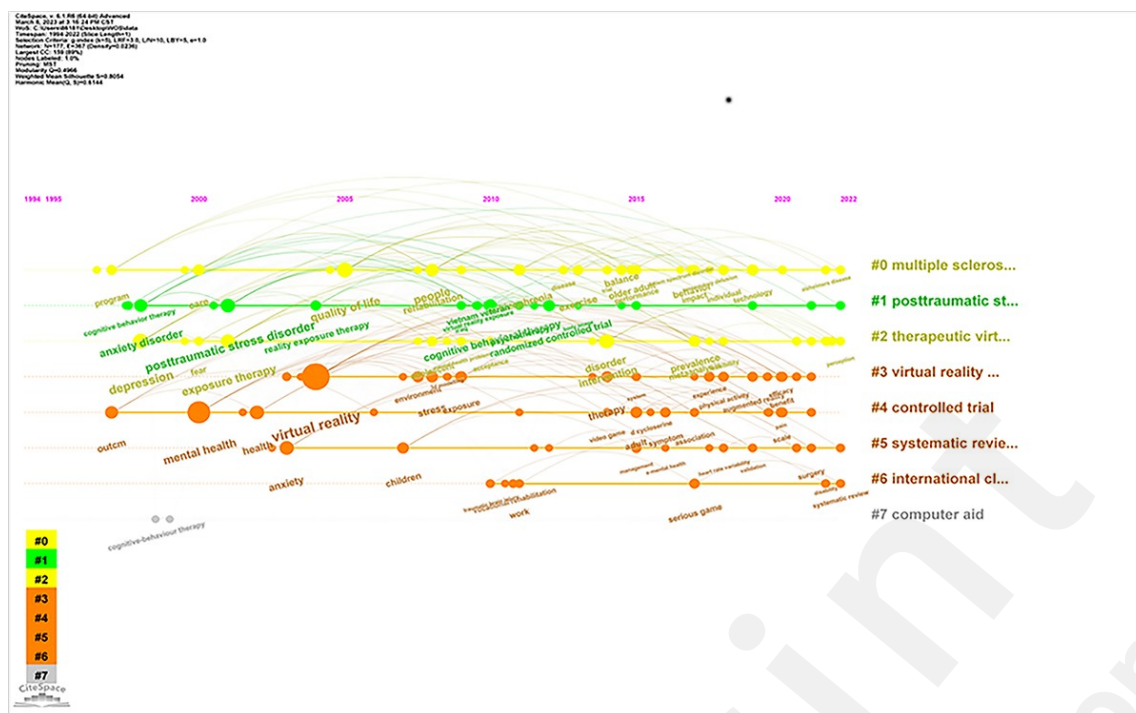


Figure 5. Timeline network of the keywords. The graph features cluster names on the left, with corresponding keywords depicted as nodes on the right. These nodes are color-coded to match specific timelines, the details of which are located in the lower right corner of the graph. The top of the graph indicates the corresponding years for each cluster.

Analysis of reference

Figure 6(a) showcases the occurrence of citation burst in the first 13 co-cited works, indicating a dramatic surge in frequency over a brief period. This phenomenon is vital for identifying and understanding research foci and trends within a specific timeframe, as well as for recognizing emerging research frontiers. Notably, the most pronounced burst is attributed to Nexhmedin Morina's 2015 publication. In Figure 3(b), the first six cluster graphs are presented, with each representing a distinct research theme in the literature: #0 Current Research, #1 Mental Health, #2 Technological Advance, #3 Current Diffusion, #4 Computer-Based Psychotherapy, and #5 Nintendo Wii. These clusters offer valuable insights into the core subjects of the co-cited literature. Supplementary Tables 3 and 4 reveal that the second most cited and central articles predominantly focus on schizophrenia and anxiety, while the most cited work is a comprehensive review of mental health. Viewed from a bibliometric perspective, these frequently cited papers often highlight the prevailing research

hotspots in a field. Consequently, it can be inferred that schizophrenia and anxiety are major areas of focus within this domain. Moreover, it is likely that Cluster #2, 'Therapeutic Virtual Reality' in Figure 2, pertains to these specific conditions, further emphasizing their significance in current VR research.

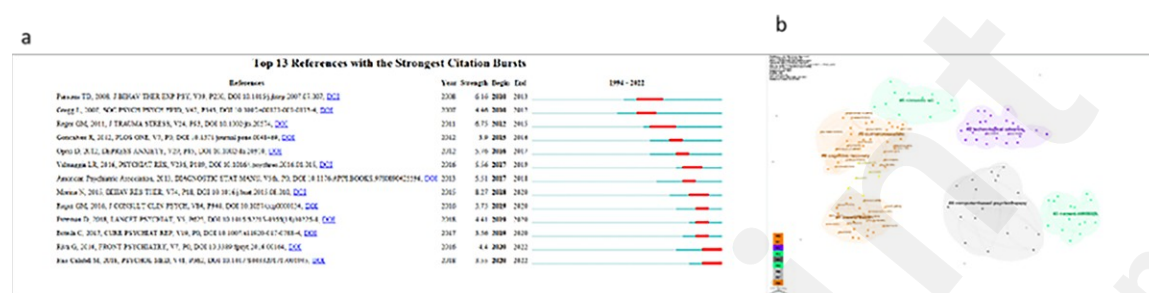


Figure 6. cited references map. (a) top 13 references with the strongest citation bursts. The 'start' and 'end' labels mark the burst's duration, while the 'intensity' value indicates its significance, with a higher value denoting greater impact. Light blue signifies the overall study period, whereas red highlights the burst's commencement and conclusion. (b) network of co-cited references of virtual reality for mental health.

Analysis of keyword burstness

The diagram in Figure 7 provides an illustration of the top 14 most frequently cited keywords in VR research within the mental health domain, showcasing the prevailing research hotspots. The blue line on the timeline and the periods of citation bursts (red line) for these keywords [33, 34] are presented. Notably, the 'strength' of the citation bursts for the keywords 'randomized controlled trial,' 'reality exposure therapy,' and 'schizophrenia' indicate their strong impact, emphasizing the significant focus on the clinical application of VR technology in psychotherapy. Initially, the primary research focus was on various treatment methods and disorders, with 'fear' and 'reality exposure therapy' garnering considerable attention for approximately 13 and 14 years, respectively. However, in the past three years, the research emphasis has shifted towards individual and environmental factors. Consequently, the emergence of the keywords 'pain' and 'environment' in 2020 signifies potential new frontiers for research in this field, reflecting the evolving landscape of research within

the mental health domain.



Figure 7. top 14 keywords with the strongest citation bursts.

Discussion

This study conducted a bibliometric analysis of publications focusing on VR technology in the context of mental health from 1994 to 2022, using the WOS database. The analysis also encompassed a review of developmental trends in the field. Historically, VR technology has played a significant role in mental health interventions. In recent years, its application has become increasingly systematic and mature, positioning VR as a viable tool for both general and specialized healthcare services [3, 35].

Discussion of results

The trajectory of VR technology in mental health research can be categorized into three phases based on annual publication outputs. The Incubation Period (1994–2007) was characterized by minimal output, with annual publications predominantly in the single digits. The Slow Growth Period (2007–2018) saw consistent but limited activity, with fewer than 10 publications per year. The Rapid Growth Stage (post-2018) marked a substantial surge, with annual publications escalating

from 58 to 219. This progression indicates a shift from theoretical exploration toward practical application, reflecting enhancements in both the quantity and quality of research [36, 37].

Institutions such as Harvard Medical School, Boston University, and Northwestern University have produced high-impact research; however, the collaborative network among institutions remains fragmented, with limited cross-institutional cooperation. This lack of integration may lead to inefficient resource use, duplicated efforts, and constrained research depth and reproducibility [27, 38]. Future efforts should encourage interdisciplinary collaboration and increase investment in hardware, software, and platform development to foster innovation and systematic solutions [4, 39].

Giuseppe Riva, with 11 publications, is the most prolific author in this domain. His work, including the recent review "*The Promise of the Metaverse in Mental Health: The New Era of MEDverse*," systematically evaluates VR's efficacy across psychological disorders and introduces the concept of VR as a transformative communication medium that transcends physical self-representation [40]. Per Carlbring, focusing on anxiety and phobias, has contributed seven articles. His research on automated VR exposure therapy for spider phobia suggests that virtual interventions may lower the threshold for subsequent in-vivo exposure, highlighting a sequential treatment advantage [41]. Andrea Gaggioli, another leading contributor, has explored the role of VR and AR in enhancing personal and clinical change through immersive and emotionally engaging experiences, as evidenced in his highly cited work [42].

The most cited authors, including Daniel Freeman (125 citations), Rothbaum BO (centrality 0.35), and Riva G (centrality 0.16, 115 citations), underscore their influential roles. Freeman's comprehensive review illustrates VR's potential to improve the accessibility and efficacy of mental health treatments by simulating real-world environments [36]. Additionally, a randomized controlled trial combining VR exposure with D-cycloserine for PTSD demonstrated how genetic markers and comorbidity could guide personalized treatment [43]. Riva's innovative VR training protocol for cancer patients integrates exposure, out-of-body experiences, and body-swapping techniques to

enhance coping strategies and stress tolerance [44].



Figure 8. Analysis of cited author. the centrality index, specifically betweenness centrality, is employed to evaluate the centrality of authors in each network. Nodes with high centrality (greater than 0.1) are typically regarded as turning points or pivotal points within a field. Nodes surrounded by a purple ring denote a higher centrality, indicating the influential role of these authors in the field.

In terms of the most cited articles, as presented in Tables 2 and figure 8, The top-cited articles were published in *Psychological Medicine*, *Journal of Anxiety Disorders*, and *Psychiatry Research*. Freeman's invited review systematically covers two decades of VR applications in mental health [36]. Carl's meta-analysis establishes virtual reality exposure therapy (VRET) as comparably effective to in-vivo exposure for anxiety disorders [37]. The most central paper validates VR-based cognitive interventions for schizophrenia rehabilitation, highlighting its potential to improve functional outcomes [45].

Table 2 Top 5 Cited References with the Highest Frequency Related to Virtual Reality for Mental Health.

ranking	frequency	reference	author	and
---------	-----------	-----------	--------	-----

			publication year	
1	87	Virtual reality in the assessment, understanding, and	Freeman D (2017)	
2	48	treatment of mental health disorders Virtual reality exposure therapy for anxiety and	Carl E (2019)	
3	44	related disorders: A meta-analysis of randomized controlled trials Virtual reality in the psychological treatment for	Valmaggia	LR
4	36	mental health problems: An systematic review of	(2016)	
5	27	recent evidence The use of virtual reality technology in the treatment	Maples-Keller	JL
		of anxiety and other psychiatric disorders	(2017)	
		Virtual reality in the assessment and treatment of	Rus-Calafell	M
		psychosis: a systematic review of its utility,	(2018)	
		acceptability and effectiveness		

Research hotspots

Burst detection, a method used to identify significant surges in keyword prevalence over a specific period, is a crucial indicator of evolving research hotspots [46, 47]. And keyword burst analysis and cluster mapping identify post-traumatic stress disorder, anxiety disorders, and schizophrenia as dominant research hotspots over the past two decades, indicating a consolidated research focus that facilitates resource allocation and thematic depth.

VR is increasingly recognized for its application in treating anxiety and post-traumatic stress disorder (PTSD) [48-53]. Anxiety disorders, among the most prevalent mental health conditions, have traditionally been treated through cognitive behavioral therapy (CBT) and/or medication [54]. In recent years, VR interventions have expanded to include treatment for depression, anxiety, and phobias, but their impact varies by the area of application. For example, Jaquez et al reported reduced perioperative anxiety in pediatric patients using VR combined with noise-canceling headphones [55], whereas Cieslik et al found no significant anxiety reduction before coronary

angiography using a VR mask [56]. These conflicting outcomes underscore the need for further context-specific clinical validation . These conflicting outcomes underscore the need for further context-specific clinical validation.

In schizophrenia, VR has been used to address hallucinations, social skill deficits, and cognitive impairments. VR-based social skills training has shown promise in enhancing conversational ability and self-efficacy through role-playing in simulated environments [57, 58].

Research frontier and trend

Keywords in literature research are foundational elements that illuminate the primary research hotspots and frontiers in a specific field [46]. Analyzing of co-occurrence of keywords provides insights into the evolving trends and focal points within a specific domain [59]. From 2000 to 2018, prominent keywords included exposure therapy, PTSD, fear, schizophrenia, and anxiety disorders. Since 2018, “pain” and “environment” have emerged as rapidly evolving themes, reflecting new directions in VR research such as pain management and adaptive virtual environments. For example, VR's ability to alter distraction levels, subjective pain intensity, and brain activity has been shown to produce pain relief compared to moderate hydromorphone [60, 61]. Moreover, the use of immersive VR during active labor has been demonstrated to effectively reduce sensory pain, maternal heart rate (HR) and mean arterial pressure (MAP) [62].

VR environments offer reusable, customizable simulations for training and therapeutic purposes. For instance, VR ambulance configurations allow emergency personnel to optimize patient handling and vehicle positioning [63, 64]. Integration with biometric measures like EEG has enabled real-time monitoring of mental states during VR simulations, paving the way for personalized training modules aimed at improving learning and performance [65].

This study has several limitations. This study is subject to several limitations. First, the exclusive reliance on the WOS database may constrain the scope of the analysis. While WOS is a principal data source for bibliometric studies [66, 67] , its coverage is not exhaustive, potentially

leading to an underrepresentation of relevant literature and a constrained understanding of the field's knowledge structure. Future investigations would benefit from integrating multiple databases (e.g., Scopus, Dimensions) or employing multi-source data fusion tools (e.g., KKKU-BiblioMerge) to enhance data comprehensiveness and representativeness [68].

Second, despite implementing standardized analytical protocols, an inherent degree of interpretive bias persists in processes such as literature screening, keyword definition, and data extraction. Such subjectivity may affect the consistency, reproducibility, and generalizability of the findings. Utilizing standardized software (e.g., Bibliometrix) and fostering interdisciplinary collaboration in future studies could mitigate this bias.

Finally, as a bibliometric analysis, this study focuses on mapping the intellectual structure of VR research in mental health rather than providing an in-depth discussion of specific research content. Consequently, the interpretive power of the results is primarily descriptive, offering limited direct guidance for clinical application.

Conclusion

Our findings indicate the research trend of VR in mental health is pain and environment, and the research hotspots are post-traumatic stress disorder, anxiety disorder, and schizophrenia. The integration of virtual reality has increased significantly in different areas, including daily life, educational environments, and healthcare systems [69, 70]. The investigation into Oculus Rift's potential in education [71] and healthcare [72] exemplifies the broadening scope of VR applications. This trend underlines a burgeoning interest in harnessing VR for mental health interventions. These insights from this study not only deepen the academic community's understanding of VR's multifaceted applications in mental health but also highlight its potential as a transformative tool in this field.

Acknowledgments

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Conflict of Interest

No potential conflict of interest was reported by the authors.

Data availability

The authors confirm that all pertinent data are contained within the manuscript and the multimedia appendices. Data are available from the corresponding author upon reasonable request.

Author Contributions

Nannan Li: conceptualization of the review, selection of studies, data extraction, writing and editing of original draft; Wenzhuo Wei: conceptualization of the review and data quality; Lijun Ma: conceptualization of the review and editing of original draft; He Du: data extraction and data quality; Mengchen Zhang: data extraction and selection of studies; Deng Jie: selection of studies; Xiaoming Li: propose concepts, directing research, supervision, writing and editing of final draft.

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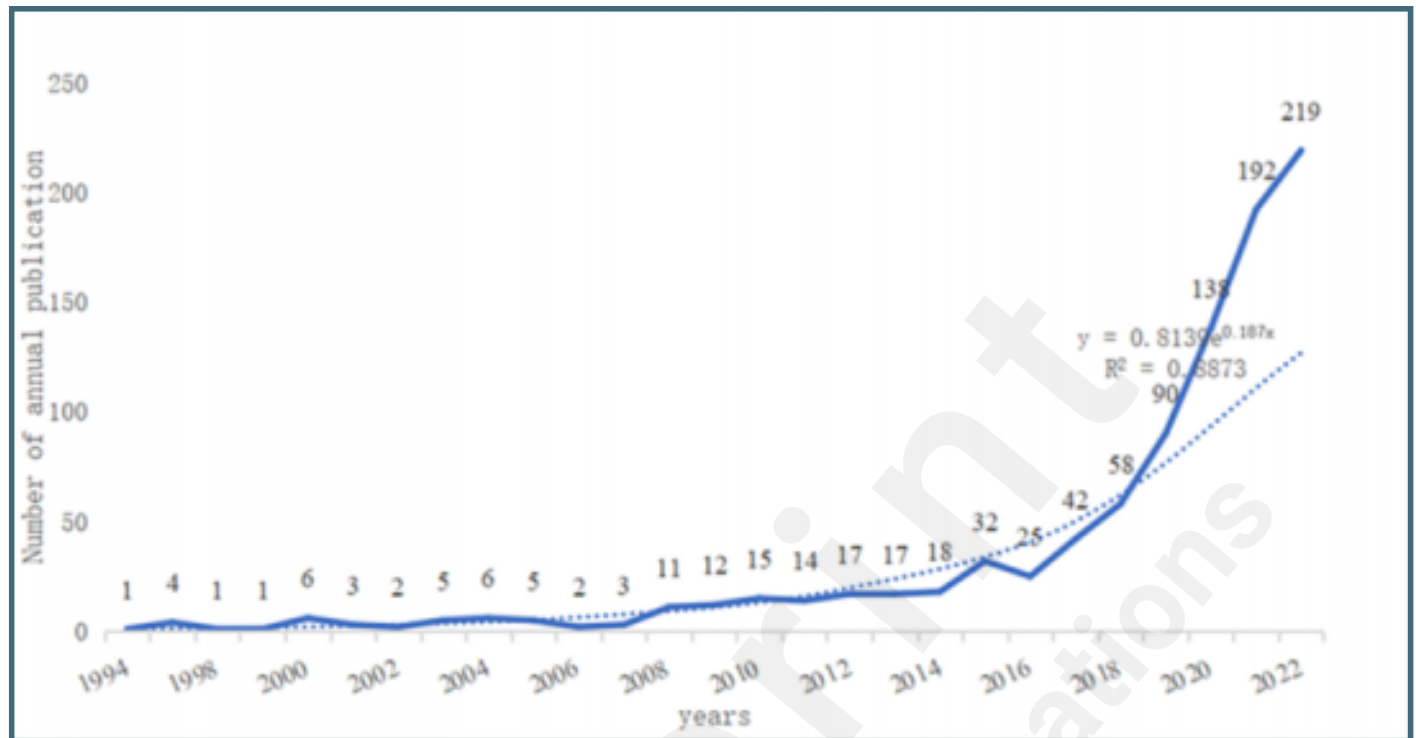
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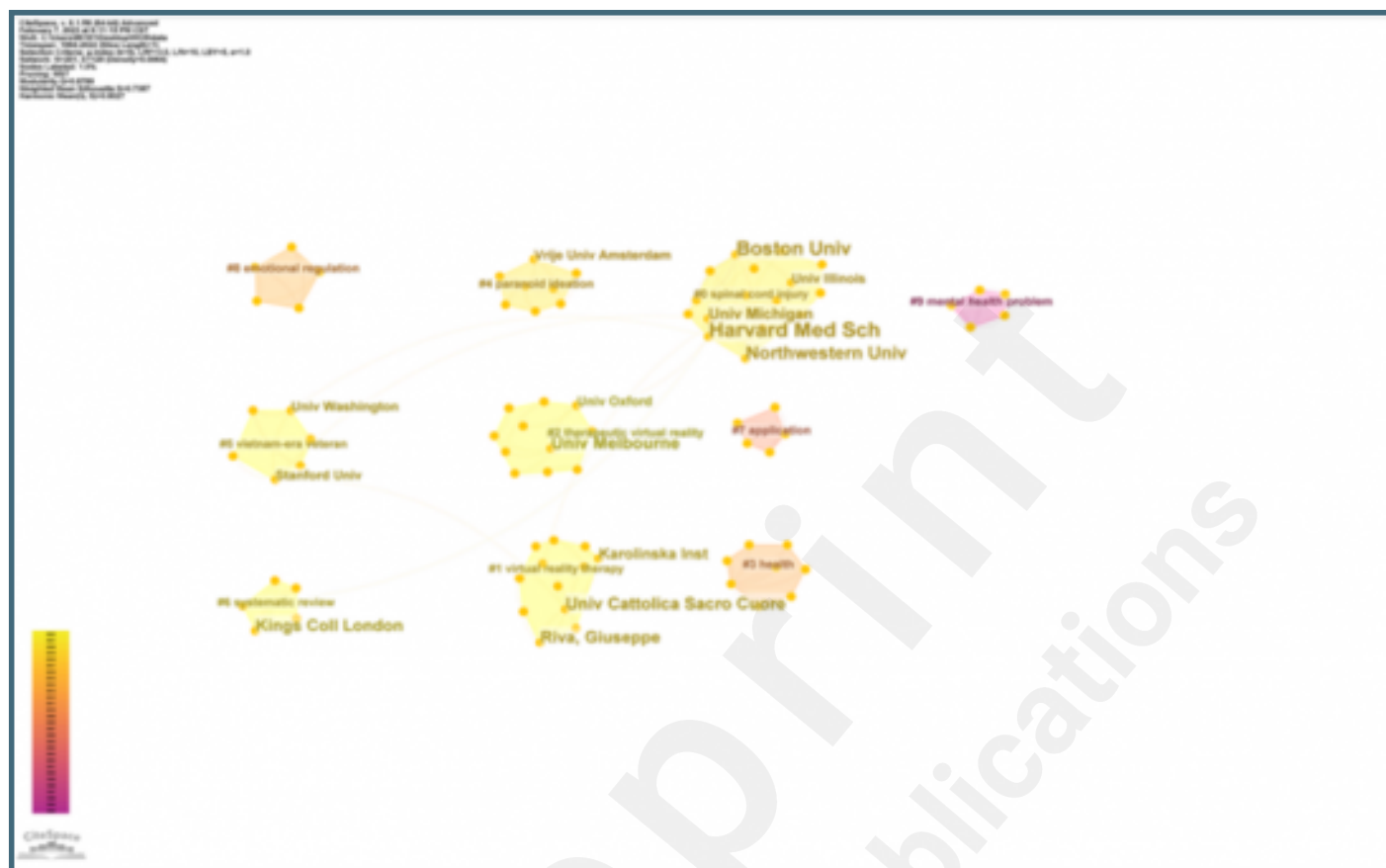
Supplementary Files

Figures

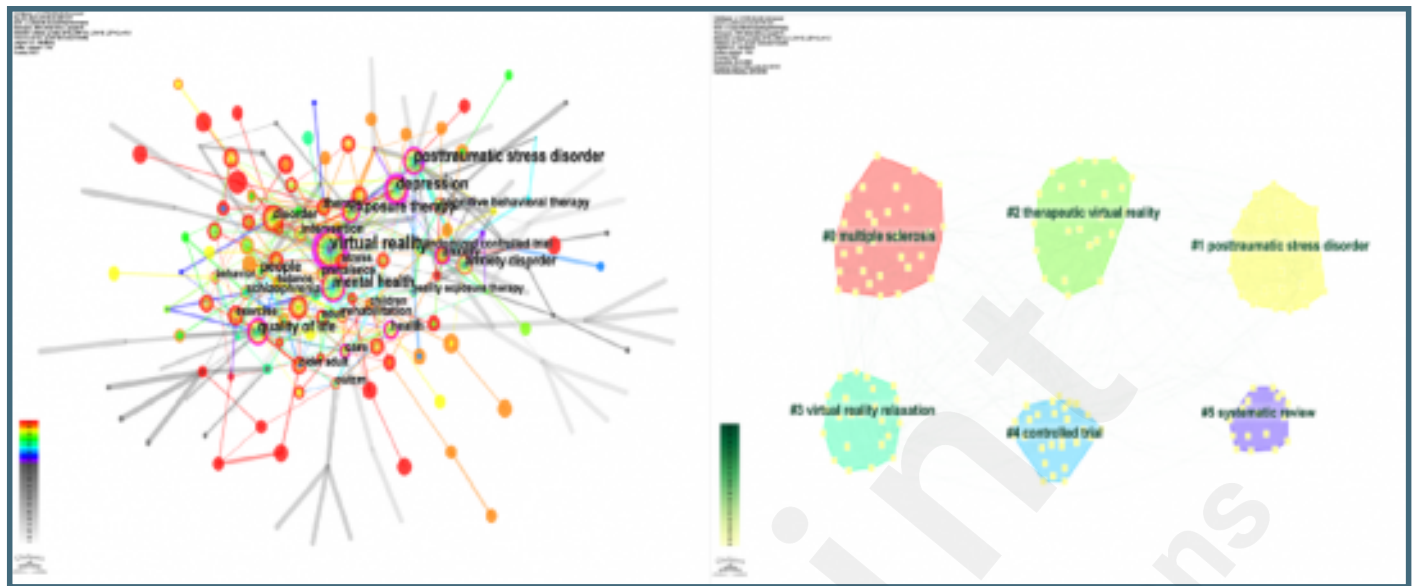
Annual publications in virtual reality for mental health.



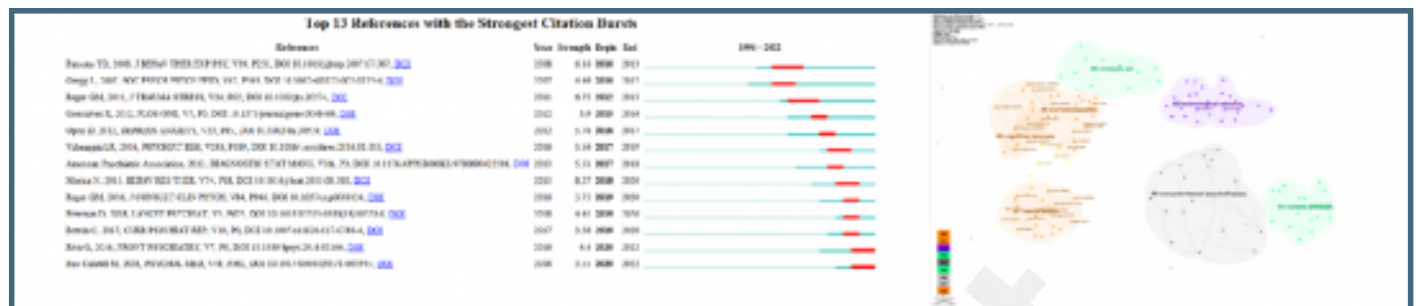
Analysis of author and institution.



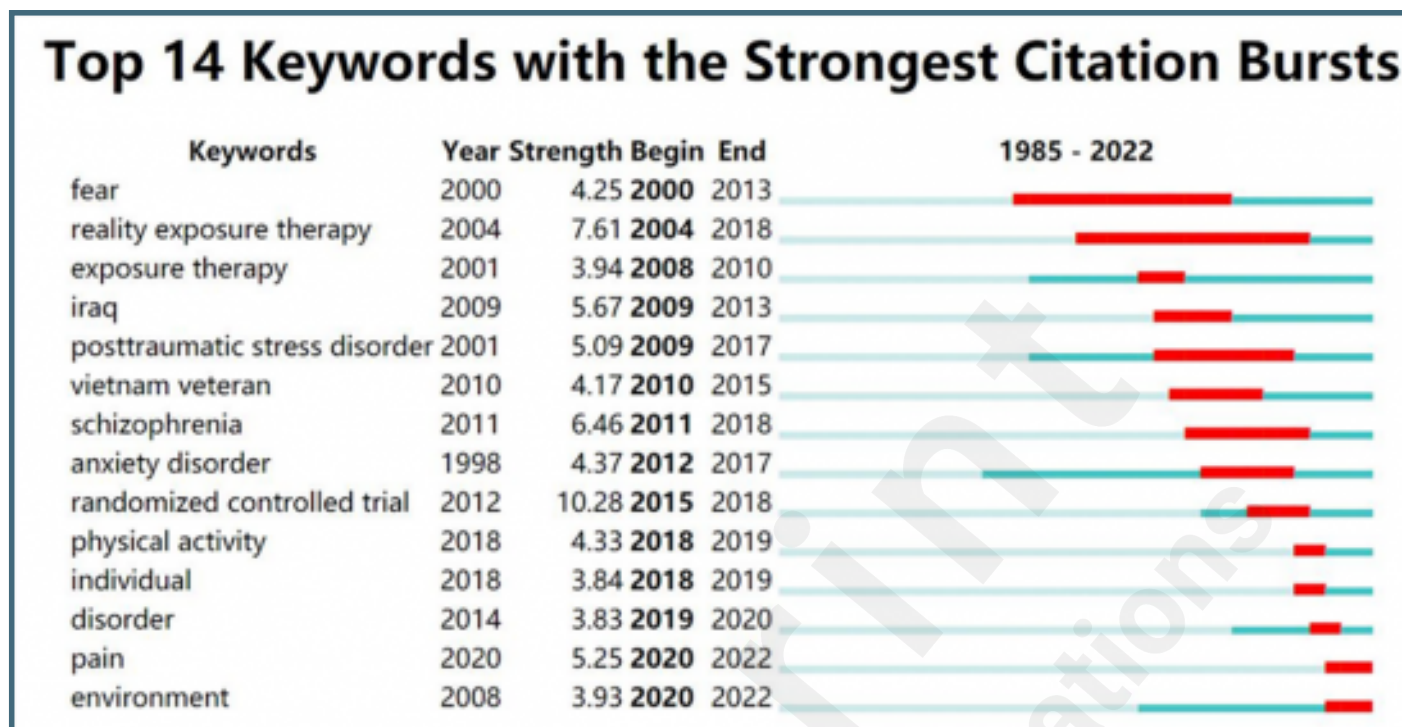
Keyword co-occurrence and keyword clustering.



cited references map. Top 13 references with the strongest citation bursts and the network of co-cited references of virtual reality for mental health.



Top 14 keywords with the strongest citation bursts.



Multimedia Appendixes

Supplementary Materials.

URL: <http://asset.jmir.pub/assets/19f9aab186336be560842d8279fba55b.docx>



Related publication(s) - for reviewers eyes onlies

Highlight.

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