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RECEIVED 09 March 2026

REVISED 05 May 2026

ACCEPTED 11 May 2026

PUBLISHED 28 May 2026

CITATION

Cinar OE (2026) Virtual reality exposure therapy: a systematic review and bibliometric analysis of clinical applications and research trends. *Front. Virtual Real.* 7:1826777. doi: 10.3389/frvir.2026.1826777

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Virtual reality exposure therapy: a systematic review and bibliometric analysis of clinical applications and research trends

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Introduction: This systematic review and bibliometric analysis investigates the evolution of Virtual Reality Exposure Therapy (VRET) from 2015 to 2025, identifying core research themes and clinical application domains to map the field's intellectual structure.

Methods: An extensive literature search was conducted across Scopus and Web of Science, resulting in a deduplicated corpus of 1,583 unique publications. A quantitative bibliometric analysis using the Bibliometrix R package was integrated with a qualitative thematic synthesis of 40 highly relevant studies.

Results: The analysis reveals a steady expansion of the field across 720 journals and involving 6,485 authors, with annual publications rising from 76 in 2015 to 281 in 2025 (an annual growth rate of 13.97%). Science mapping and keyword co-occurrence analysis identified three primary thematic clusters: core clinical VRET applications, study design/participant characterization, and pain management. Qualitative synthesis confirms VRET remains most established in treating specific phobias, social anxiety disorder, PTSD, panic disorder, and eating disorders, with emerging integration patterns converging around AI-adaptive systems, biofeedback architectures, and digital twin frameworks.

Discussion: Thematic mapping indicates that despite significant volume growth, the field has yet to consolidate around a single, dominant integrative paradigm. Critical gaps remain, most notably the scarcity of large-scale randomized controlled trials (RCTs) and health economic evaluations. Ultimately, these findings provide a roadmap for future innovation toward AI-driven, globally accessible VRET systems.

KEYWORDS

anxiety disorders, bibliometric analysis, cognitive behavioral therapy, digital therapeutics, immersive technology, PTSD, virtual reality exposure therapy

1 Introduction

1.1 Clinical background and burden of anxiety-spectrum disorders

Anxiety-spectrum disorders are among the most common and costly mental health conditions worldwide. Data shows that about 284 million people are affected globally, leading to significant disability across all ages and economic backgrounds (Bandelow et al., 2023; Whiteford et al., 2013). While standard medication and therapy work for some, they face major hurdles. These include high dropout rates of 20–30 percent for exposure therapies, a lack of available therapists, and geographic barriers. Additionally, it is

logistically difficult to provide traditional in-person exposure therapy with the steady control needed for the best results (Emmelkamp and Meyerbröcker, 2021; Carl et al., 2019). Because of these issues, there is growing interest in technology-based interventions. These tools can provide evidence-based exposure therapy with more flexibility and better scaling than traditional clinics. Virtual Reality Exposure Therapy (VRET) has become the most thoroughly researched and supported option among these new methods.

VRET puts the basic principles of exposure therapy (fear activation, inhibitory learning, and the strengthening of extinction) into practice through immersive computer environments. These digital spaces allow for the presentation of feared stimuli in a way that is standardised, repeatable, and precisely controlled (Morina et al., 2015; Botella et al., 2017).

Three main concepts support how VRET works. First is presence, which is the personal feeling of “being there” in the virtual world; this acts as the main psychological bridge to trigger fear. Second is immersion, which refers to the actual technical ability of the hardware and software to create a surrounding sensory environment. Third is embodiment, or the extent to which a patient feels a virtual body is their own, a factor that is especially important for treating trauma or body image issues (Riva et al., 2019; Maples-Keller et al., 2017).

Compared to imaginal exposure, VRET has a clear clinical benefit because it does not require the patient to create vivid mental images. This is helpful for trauma survivors who may struggle with imagery or for patients who avoid mentally engaging with their fears during traditional therapy. The technology has changed significantly since it started. It has moved from the costly, lab-based CAVE systems of the 1990s to modern, affordable headsets that work wirelessly and do not need a specialized technical setup (Philippe et al., 2022; Rizzo and Koenig, 2017).

1.2 Research landscape and justification for bibliometric analysis

Even after 20 years of VRET development, the field still lacks a thorough quantitative map of its intellectual structure, collaboration networks, thematic changes, and publication trends for the entire 2015 to 2025 period. Past reviews have mostly focused on meta-analyses for specific disorders. Most notably (Carl et al., 2019), looked at anxiety disorders in general (Opriş et al., 2012), focused on specific phobias, and (Kothgassner et al., 2019) examined PTSD. Other works have provided narrative reviews of certain technical advances, but none have used bibliometric science mapping to describe the overall intellectual architecture or measure the structural traits of the field across all clinical areas at once.

Bibliometric analysis is a necessary addition to a systematic review because it allows for a quantitative look at a field's structure that a qualitative summary cannot provide. This includes citation network patterns, the boundaries of thematic clusters, how concepts rise and fall over time, and international partnership trends (Donthu et al., 2021). Earlier bibliometric reviews concerning VR in clinical settings have focused on rehabilitation (Laver et al., 2025), managing pain, or specific types of disorders. However, none have fully mapped VRET as one unified field covering all clinical areas, technical aspects, and the complete 2015 to 2025 growth era. This study addresses that gap

by offering both structural bibliometric mapping and a qualitative clinical summary in one combined analysis.

Research gaps in the current literature can be divided into three areas:

- Theoretically, most trial designs do not properly show how hardware immersion leads to clinical results, particularly the path from feeling present in a virtual space to achieving extinction learning.
- Methodologically, there is a lack of standardised ways to measure outcomes and a shortage of long-term follow-up studies. This prevents the precise combination of data from different studies that is needed to create clinical guidelines.
- Empirically, several important clinical areas still lack enough evidence from controlled trials to support official recommendations. These include using VRET for depression as a main goal, treating OCD types other than those involving contamination, and addressing anxiety in elderly patients.

1.3 Research objectives

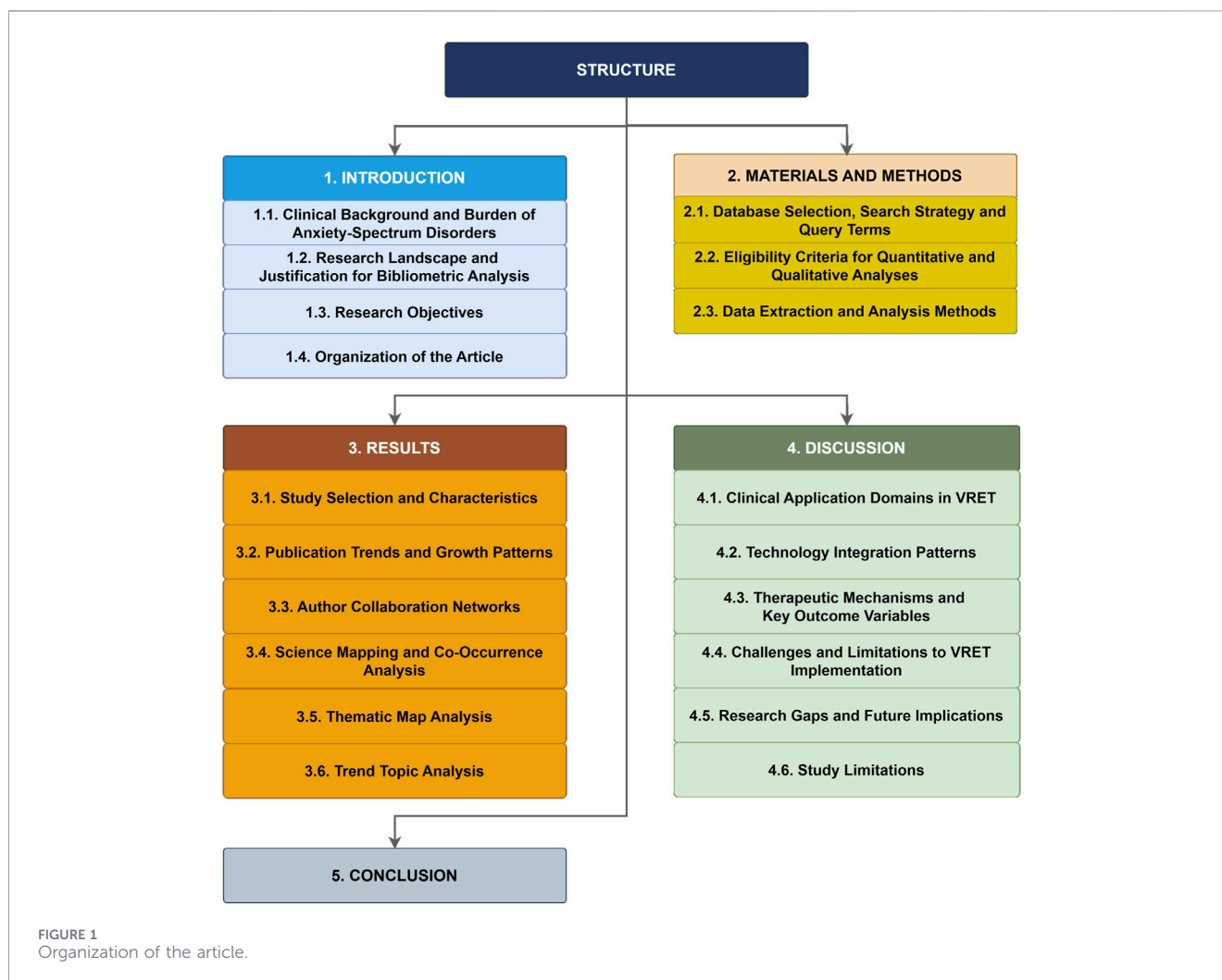
This systematic review and bibliometric analysis has four main objectives:

1. To evaluate the scholarly evolution of the field by quantifying growth trends, citation impact, and the distribution of research across global institutions and specialized journals;
2. To map the conceptual structure and intellectual boundaries of VRET by identifying the dominant thematic clusters and tracking how research priorities have shifted over the last decade;
3. To assess the clinical effectiveness and implementation characteristics of the most influential VRET studies across diverse mental health domains; and
4. To establish a strategic roadmap for the field by identifying existing research gaps and defining priorities for future clinical and technical development.

Each of these goals is covered in the Results and Discussion sections. Objective 1 is found in Sections 3.1 through 3.4, Objective 2 is in Sections 3.5 and 3.6, Objective 3 is in Sections 4.1 through 4.4, and Objective 4 is in Section 4.5.

1.4 Organization of the article

As shown in Figure 1, the article is structured into five cohesive sections, beginning with an Introduction that establishes the clinical background of anxiety-spectrum disorders and justifies the research objectives. This is followed by Materials and Methods, which details the database search strategy, eligibility criteria, and data extraction protocols. The Results section presents a comprehensive bibliometric overview, including publication trends, author networks, and thematic mapping. These findings are interpreted in the Discussion, which explores clinical application domains, technology integration, and therapeutic mechanisms while addressing implementation challenges and research gaps. Finally, the Conclusion synthesizes the key insights and provides a closing summary of the study's contributions to the field.



2 Materials and methods

2.1 Database selection, search strategy and query terms

Scopus and Web of Science were selected as the indexing databases for this study because they offer the most comprehensive coverage of peer-reviewed literature in clinical psychology, psychiatry, and computer science regarding VRET. These platforms provide the robust, structured bibliometric metadata required for science mapping and are recognized as the standard dual-database pairing for systematic bibliometric reviews (Donthu et al., 2021).

PubMed was not used as a primary database because its tools for exporting bibliometric data are limited compared to Scopus and Web of Science, and its medical content overlaps significantly with what is already in Scopus. PsycINFO was excluded because it lacks the citation network and keyword data required for Bibliometrix-based science mapping. While IEEE Xplore was considered, it was left out because its focus on electrical engineering and hardware would have brought in too much irrelevant content. Future research might consider adding PubMed and PsycINFO searches to find clinical trial registrations that these two primary databases might miss.

In terms of conceptual boundaries, this review focuses on Virtual Reality (VR) defined as fully immersive digital environments viewed through head-mounted displays or CAVE systems. Augmented Reality (AR) and Mixed Reality (MR) are included only when they are the main way the exposure is delivered. Non-immersive and screen-based virtual environments are excluded because they do not reach the level of presence required to be classified as VRET.

Conference proceedings were left out of the main analysis because the bibliometric data for these papers in Scopus and Web of Science lacks the citation stability and source metrics needed for science mapping. The authors recognize that this may mean some important contributions to human-computer interaction and VR engineering from events like CHI or IEEE VR/ISMAR were missed, which is noted as a limitation in Section 4.6.

2.1.1 Scopus query

TITLE-ABS-KEY (("virtual reality exposure therapy" OR "VRET" OR "virtual reality exposure" OR "in virtuo exposure" OR "VR-based exposure" OR "VR exposure therapy" OR "immersive exposure therapy" OR "virtual exposure therapy") AND ("anxiety" OR "anxiety disorder" OR "specific phobia" OR "social anxiety" OR "PTSD" OR "post-traumatic stress" OR "panic disorder" OR

TABLE 1 Main information about merged dataset.

Description	Results
Databases	Scopus + Web of science
Scopus articles	1,551
Web of science articles	264
Total before duplication	1,815
Duplicates removed	232
Duplication rate	12.8%
Final unique documents	1,583
Timespan	2015:2025
Sources	720
Annual growth rate	13.97
Document average age	4.85
Average citations per doc	27.8
Authors	6,485
Authors of single-authored docs	68
Single-authored docs	79
Co-authors per doc	5.9
International co-authorship %	3.917

“agoraphobia” OR “OCD” OR “eating disorder” OR “depression” OR “chronic pain” OR “addiction” OR “autism spectrum disorder” OR “psychosis”)) AND PUBYEAR >2014 AND PUBYEAR <2026 AND (LIMIT-TO (LANGUAGE, “English”)))

2.1.2 Web of science query

TS=((“virtual reality exposure therapy” OR “VRET” OR “virtual reality exposure” OR “in virtual exposure” OR “VR-based exposure” OR “VR exposure therapy” OR “immersive exposure therapy” OR “virtual exposure therapy”) AND (“anxiety” OR “anxiety disorder” OR “specific phobia” OR “social anxiety” OR “PTSD” OR “post-traumatic stress” OR “panic disorder” OR “agoraphobia” OR “OCD” OR “eating disorder” OR “depression” OR “chronic pain” OR “addiction” OR “autism spectrum disorder” OR “psychosis”)) AND PY=(2015–2025) AND LA=(English)

2.2 Eligibility criteria for quantitative and qualitative analyses

The search across dual databases resulted in the retrieval of 1,551 articles from Scopus and 264 from Web of Science, providing a total of 1,815 records published between 2015 and 2025.

To ensure a clean dataset for quantitative bibliometric analysis, the Bibliometrix mergeDbSources function was utilized to identify and eliminate 232 overlapping documents. This process revealed a duplication rate of 12.8%, culminating in a final merged corpus of 1,583 unique articles (Table 1).

The relatively low overlap observed between these two databases highlights their complementary indexing profiles within the VRET

domain. Scopus accounted for the significant majority of the records, largely due to its extensive coverage of interdisciplinary and technology-focused publications. Conversely, Web of Science served as a critical source for cross-validating the most influential core clinical literature, ensuring that the merged dataset captured both the technical and medical facets of the field.

The qualitative study selection and eligibility followed PRISMA 2020 guidelines, as shown in Figure 2 (Page et al., 2021). To be included, articles had to be peer-reviewed empirical studies published in English between 2015 and 2025 within the fields of psychology, psychiatry, neuroscience, computer science, or health sciences. They also had to focus directly on VRET as a clinical intervention. While the search terms included broader conditions like depression and psychosis to capture as much literature as possible, the final criteria required that each article specifically focus on VRET as an exposure-based treatment. Studies using VR for other types of therapy were removed during the screening process.

2.3 Data extraction and analysis methods

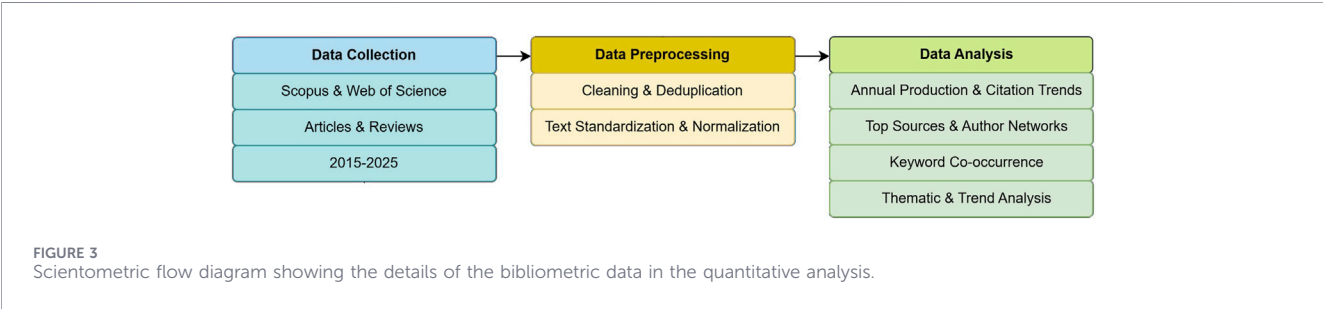
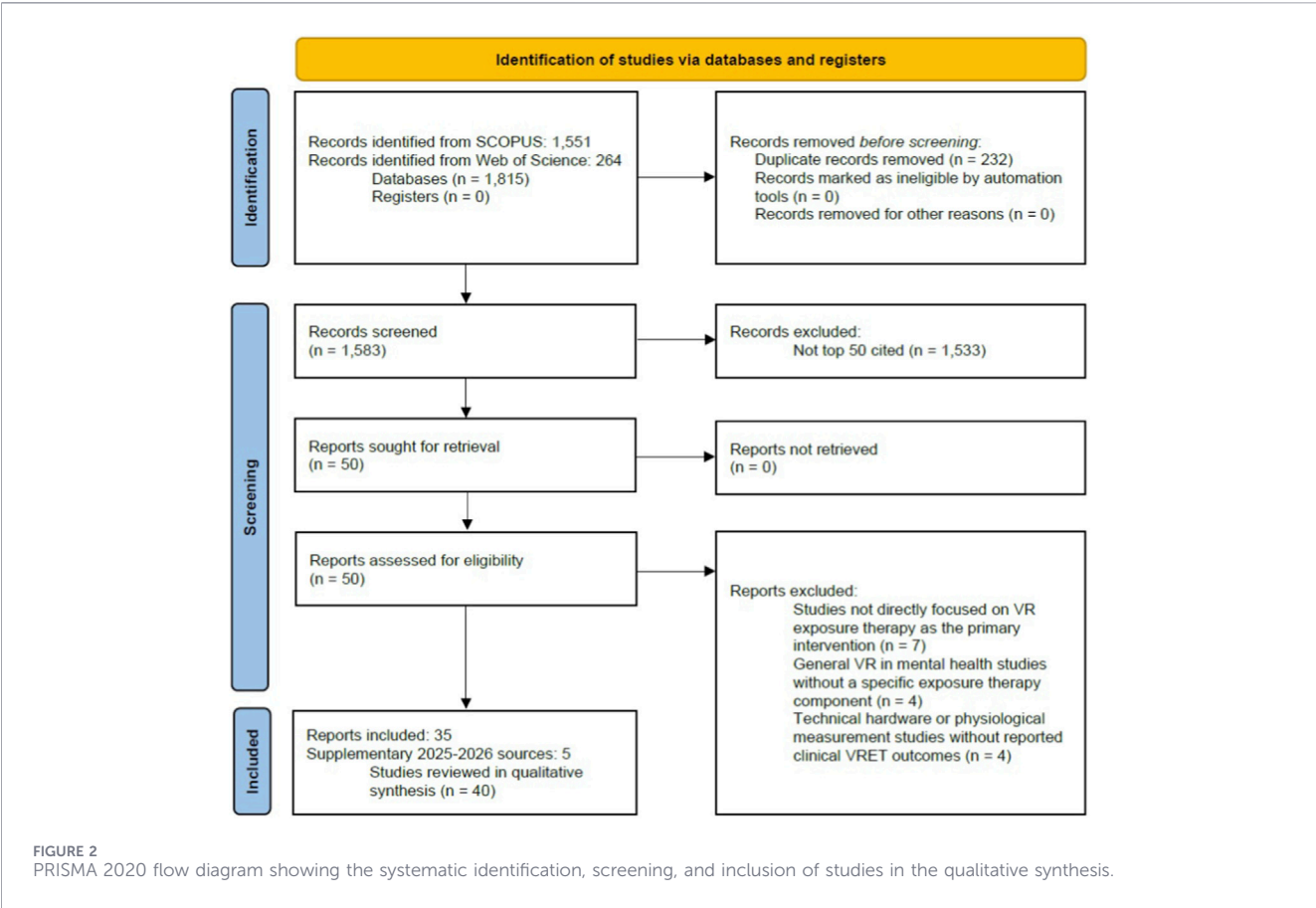
The quantitative bibliometric part of the study is organized as shown in Figure 3. For this process, data was gathered from all 1,583 articles deduplicated, including publication years, journals, authors, citations, and keywords. The analysis included productivity, citation trends and mapping how keywords appear together, analyzing thematic maps based on how central or dense certain topics are, and identifying trending topics by looking at median publication years. To keep the focus on significant terms, only keywords appearing at least 10 times were included in the network analysis. The study used association strength normalization to account for how often different keywords appear. A specific method called the Louvain clustering algorithm was used to group these topics naturally. In the resulting diagrams, the size of each point reflects its importance, while the thickness of the lines shows how often those topics appear together.

For the qualitative synthesis, 35 articles were chosen based on their high citation counts to ensure they represent the most influential work in the field. Because relying on citations naturally favors older papers, 5 recent high-quality studies, such as (Yang et al., 2025; Nedungadi et al., 2025; Bergsnev and Sánchez Laws, 2026; de Haart et al., 2026; Medeiros et al., 2026), were added to the discussion on technology and future trends even though they are too new to have reached the citation threshold. Totally, 40 selected studies were analyzed using a consistent framework. This covered the study design, the patient population, the specific VR hardware and software used, and the details of the therapy sessions, such as how long they lasted and the role of the therapist. It also tracked the results, effect sizes, and how long patients were followed after treatment as shown in Table 2.

3 Results

3.1 Publication trends and growth patterns

The temporal analysis of the 1,583-article dataset indicates a steady and sustained expansion of VRET research between 2015 and 2025, as illustrated in Figure 4.



Annual publication volume rose from 76 articles in 2015 to 281 in 2025, marking a nearly 3.7-fold increase over the 10-year period. Output remained relatively constant between 2015 and 2018, with annual counts ranging from 75 to 100 articles, before transitioning into a phase of more rapid growth starting in 2019, when the field recorded a significant increase to 148 publications.

This trajectory is reflective of the accelerating hardware accessibility and clinical validation efforts that defined VRET research in the late 2010s. This period coincided with the broader availability of consumer-grade head-mounted displays and the increasing publication of randomized controlled trial (RCT) evidence across various anxiety disorders.

This growth trend intensified after 2021, with publications climbing from 158 in 2021 to 214 in 2024 (35.4% increase) before reaching a peak of 281 articles in 2025, the highest annual output

recorded during the review period. Notably, the COVID-19 pandemic during 2020–2021 did not result in the publication disruptions observed in other clinical research areas. Instead, the consistent output of 139 articles in 2020 and 158 in 2021 suggests that the pandemic may have acted as a catalyst for VRET research. This interest was likely driven by the highlighted limitations of traditional in-person therapy and a subsequent acceleration in investment toward remote and technology-assisted mental health solutions (Horigome et al., 2020; Smith et al., 2020).

The 13.97% annual growth rate observed in the VRET literature compares favorably with broader digital health fields, where annual publication growth rates of 8%–12% have been reported for digital therapeutics generally and approximately 15% for telemedicine research, suggesting that VRET’s expansion reflects sustained

TABLE 2 Characteristics of studies included in qualitative synthesis (n = 40).

Author(s) and year	Design	Disorder	Platform	n/k	Outcome	ES	Follow-up	Technology
Morina et al. (2015)	Meta-analysis	Specific phobias	Multiple	k = 14	Behavioral assessment	$g = 1.23$	Variable	VRET vs. <i>In Vivo</i>
Botella et al. (2015)	Review	PTSD	HMD, CAVE	n = 12	PTSD symptoms	N/A	3–6 months	VRET
Shiban et al. (2015)	RCT	Spider phobia	HMD	n = 58	BAT, FSQ, SAS	$d = 1.12$	6 months	Multiple context/stimuli
Kampmann et al. (2016a)	RCT	Social anxiety disorder	HMD	n = 60	LSAS, SPS, SIAS	$d = 0.87$	3 months	VR vs. WL
Kampmann et al. (2016b)	Meta-analysis	Social anxiety disorder	HMD	k = 37	SAD scales	$g = 0.84$ (VRET)	N/A	Tech-assisted vs. Control
Pallavicini et al. (2016)	Systematic review	Stress (military context)	HMD, CAVE	k = 14	Stress resilience	N/A	N/A	VR-SMT
Reger et al. (2016)	RCT	Combat PTSD	Bravemind	n = 162	CAPS, PCL-M	$d = 1.17$	6 months	VRE vs. Imaginal exposure
Scheveneels et al. (2016)	Review	Anxiety disorders	N/A	N/A	External validity criteria	N/A	N/A	Fear extinction model
Serino et al. (2016)	Experimental study	Healthy females	HMD	n = 21	Body size estimation	N/A	None	Body swapping
Freeman et al. (2017)	Systematic review	Anxiety, psychosis, substance	HMD, CAVE	k = 285	Assessment, treatment	N/A	Variable	VR in mental health
Botella et al. (2017)	Systematic review	Specific phobias	Multiple	k = 11	Narrative synthesis	N/A	Variable	Presence, MR
Bouchard et al. (2017)	RCT	Social anxiety disorder	HMD	n = 59	LSAS, SPS, SIAS	N/A	6 months	VR vs. <i>In Vivo</i> vs. WL
Maples-Keller et al. (2017)	Narrative review	Anxiety, PTSD, SUD	Multiple	N/A	Evidence-based review	N/A	Variable	VRET vs. <i>In Vivo</i>
Rizzo and Koenig (2017)	Review	PTSD, autism, neuro-rehab	Bravemind, VRET	N/A	Narrative synthesis	N/A	N/A	Clinical readiness, ICT
Rus-Calafell et al. (2018)	Systematic review	Psychosis	HMD, CAVE, PC	k = 50	PANSS, social functioning	N/A	Variable	Avatar therapy, social VR
Salkevicius et al. (2019)	RCT	Stress	HMD	n = 34	HRV, SCL, PSS	$d = 0.55 - 0.72$	None	Personalised, biofeedback
Beidel et al. (2019)	RCT	Combat-related PTSD	HMD	n = 92	CAPS, PCL-M	N/A	12 months	TMT (VRET + skills)
Boeldt et al. (2019)	Review	Multiple	Multiple	N/A	Clinical applications	N/A	N/A	Consumer VR
Carl et al. (2019)	Meta-analysis	Anxiety and related disorders	HMD, CAVE, PC	k = 30	Standardised measures	$g = 0.78 - 0.90$	Variable	VRET vs. Control groups
Chirico and Gaggioli (2019)	Mini-review	Cancer	Multiple	N/A	Narrative synthesis	N/A	N/A	Distraction, relaxation

(Continued)

TABLE 2 Continued

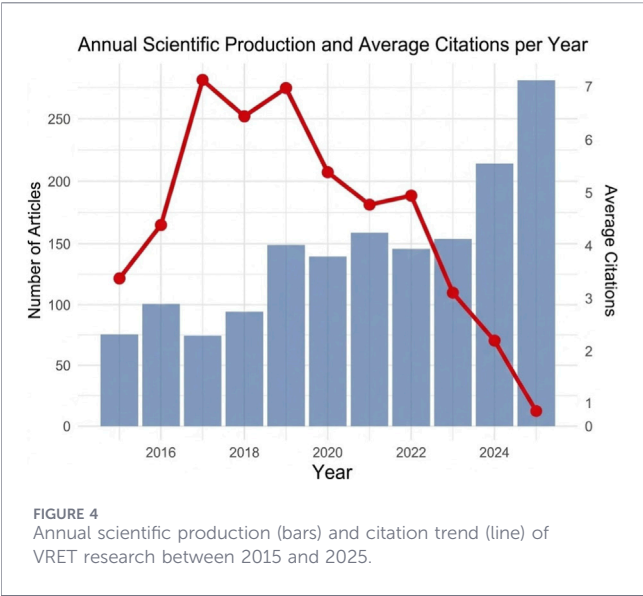
Author(s) and year	Design	Disorder	Platform	n/ k	Outcome	ES	Follow-up	Technology
Donker et al. (2019)	RCT	Acrophobia	Smartphone + cardboard/ Gear VR	n = 193	AQ, ATHQ	$d = 1.14$	3 months	Self-guided app (ZeroPhobia)
Kothgassner et al. (2019)	Meta-analysis	PTSD	Multiple	k = 9	CAPS, PCL	$g = 0.62$ (vs. Waitlist)	Variable	VRET vs. Control/Active
Lindner et al. (2019)	RCT	Public speaking anxiety	HMD	n = 50	PRCS, SSPS-N	$d = 1.67$	Variable	Therapist-led vs. Self-led
Riva et al. (2019)	Meta-review	Anxiety, eating disorders, pain	Multiple	k = 25	Meta-synthesis	N/A	None	Embodied simulation
Wechsler et al. (2019)	Systematic review and meta-analysis	Phobias	HMD	k = 9	Disorder-specific scales	$g = -0.20$	Variable	VRET vs. <i>In vivo</i>
Cieslik et al. (2020)	Systematic review	Anxiety, depression, PTSD	Multiple	k = 70	Clinical efficacy	N/A	Variable	General mental health
Emmelkamp et al. (2020)	Narrative review	Social anxiety disorder	Multiple	N/A	Clinical synthesis	N/A	N/A	Avatar interaction, VRET vs. <i>In vivo</i>
Baghaei et al. (2021)	Scoping review	Depression, anxiety	Multiple	k = 34	Clinical/Functional outcomes	N/A	N/A	Gamification, biofeedback
Emmelkamp and Meyerbröker (2021)	Review	Multiple	HMD	N/A	Treatment synthesis	N/A	N/A	HMD, presence, biofeedback
Geraets et al. (2021)	Review	Multiple	Multiple	N/A	Qualitative synthesis	N/A	N/A	Embodiment, automated VR
Karami et al. (2021)	Meta-analysis	Autism spectrum disorder	HMD, CAVE	k = 33	Social, cognitive, daily living skills	$g = 0.74$	N/A	ASD-specific, VR
Freeman et al. (2022)	RCT	Psychosis	HMD	n = 346	O-CDQ, SiAS	$d = 0.49$	Variable	Automated VR
Philippe et al. (2022)	Meta-review	Multiple	Digital health	k = 304	Clinical efficacy	N/A	N/A	Digital transformation, COVID-19 context
Usmani et al. (2022)	Narrative review	Multiple	Metaverse	N/A	Qualitative synthesis	N/A	N/A	Metaverse, NFTs, ethics
Wiebe et al. (2022)	Systematic review	Multiple	HMD, CAVE	k = 721	Diagnostics&therapy	N/A	N/A	Extensive evidence map
Yang et al. (2025)	Systematic review	Autism spectrum disorder	Immersive and non-immersive VR	k = 14	Social skills	N/A	N/A	Children and adolescents
Nedungadi et al. (2025)	Original research (Mixed methods)	Medical education	Virtual patient simulations	n = 210	Knowledge gain	N/A	N/A	Virtual patient, case-based learning
de Haart et al. (2026)	RCT	PTSD	HMD	n = 158	CAPS-5, PCL-5	N/A	Variable	VR exposure + physical activity
Medeiros et al. (2026)	Scoping review	Critical care	VR	k = 28	Clinical and educational impacts	N/A	N/A	Pain/Anxiety management, staff training

(Continued)

TABLE 2 Continued

Author(s) and year	Design	Disorder	Platform	n/ k	Outcome	ES	Follow-up	Technology
Bergsnev and Sánchez Laws (2026)	Systematic review	Anxiety and fear-related disorders	VR	k = 23	AI-driven personalisation	N/A	N/A	ML, conversational AI

Abbreviations: AQ, acrophobia questionnaire; ATHQ, attitudes towards heights questionnaire; BAT, behavioral avoidance test; Bravemind, VR, exposure system for PTSD; CAPS/CAPS-5, Clinician-Administered PTSD, scale; CAVE, cave automatic virtual environment; ES, effect size; FSQ, fear of spiders questionnaire; HMD, head-mounted display; HRV, heart rate variability; ICT, information and communication technology; k = number of included studies (reviews/meta-analyses); LSAS, liebowitz social anxiety scale; ML, machine learning; MR, mixed reality; n, number of participants (primary studies); N/A, not applicable; NFT, Non-fungible token; O-CDQ, oxford cognitions and defences questionnaire; PANSS, positive and negative syndrome scale; PCL-M/PCL-5, PTSD, Checklist (Military/Version 5); PRCS, personal report of confidence as a speaker; PSS, perceived stress scale; RCT, randomised controlled trial; SAD, social anxiety disorder; SAS, spider phobia questionnaire; SCL, skin conductance level; SIAS, social interaction anxiety scale; SiAS, social anhedonia scale; SPS, social phobia scale; SSPS-N, Social Phobia Self-Statements Scale-Negative; SUD, substance use disorder; WL, waiting list.



field-level momentum rather than isolated publication inflation (Donthu et al., 2021). The duplication rate of 12.8% between Scopus and Web of Science is consistent with overlap rates

reported in other mental health bibliometric studies and confirms that both databases contribute unique coverage to the merged corpus.

The citation metrics detailed in Table 3 highlight significant temporal shifts in research impact across the unified dataset. As expected, older publications exhibit higher mean citations per article, reflecting the extended duration available for citation accumulation. Specifically, 2017 recorded the highest mean total citations per article (71.24), followed by 2018 (57.91) and 2019 (55.72). When normalizing for differing citable lifespans using the mean citations per year metric, 2017 remained the most impactful year with an annual citation rate of 7.12 per article, followed by 2019 (6.96) and 2018 (6.43). These figures suggest that the 2017–2019 period was a particularly influential era that produced the foundational research shaping the subsequent intellectual development of the VRET field.

As expected, more recent publications show lower absolute citation counts because of their limited visibility windows; articles from 2024 averaged 6.58 total citations (2.19 per year), while 2025 articles averaged 1.67 citations. Nevertheless, the accelerating volume of publications indicates that collective knowledge production in VRET has reached its zenith within the current review period, reflecting a field that continues to expand in both scope and scholarly output.

TABLE 3 Citation performance by year (merged dataset).

Year	Articles	Mean citations per article	Mean citations per year	Citable years
2015	76	40.13	3.36	12
2016	100	48.14	4.38	11
2017	75	71.24	7.12	10
2018	94	57.91	6.43	9
2019	148	55.72	6.96	8
2020	139	37.63	5.38	7
2021	158	28.56	4.76	6
2022	145	24.66	4.93	5
2023	153	12.41	3.1	4
2024	214	6.58	2.19	3
2025	281	1.67	0.84	2

The research landscape within the 1,583-article dataset is characterized by several key journals that maintain a sustained focus on VRET and the application of immersive technology in clinical contexts (Table 4). Cyberpsychology, Behavior, and Social Networking was identified as the leading venue with 32 articles, reflecting the field's deep roots in the psychosocial and behavioral aspects of virtual interaction. This was followed closely by Trials (30 articles), which underscores the critical role that RCT methodology plays in building the clinical evidence base for VRET. The Journal of Medical Internet Research contributed 29 articles, further establishing digital health and technology-assisted interventions as a central pillar of the literature. Additionally, the International Journal of Environmental Research and Public Health (IJERPH) and Public Health and the Journal of Anxiety Disorders each published 26 articles, confirming that anxiety-spectrum conditions remain the primary clinical focus of the field.

The diverse range of journals highlights reflects the multidisciplinary framework of VRET research, which effectively bridges clinical psychology, psychiatry, digital health, and specialized VR technology. BMJ Open and Frontiers in Psychiatry contributed 25 articles each, demonstrating consistent engagement from the mainstream psychiatric community. Meanwhile, the Journal of Clinical Medicine (24 articles) and PLOS ONE (21 articles) indicate a broad interest in VRET that extends beyond specialist psychology circles. The Annual Review of Cybertherapy and Telemedicine, with 18 articles, has established itself as a dedicated specialized venue for research focusing on immersive therapeutic technologies.

The inclusion of foundational clinical psychology journals, such as Behaviour Research and Therapy (16 articles), BMC Psychiatry (15 articles), and Psychological Medicine (12 articles), reflects the strong theoretical anchoring of VRET within established cognitive-behavioral and experimental psychopathology traditions. Furthermore, rehabilitation-focused outlets like the Journal of Neuroengineering and Rehabilitation (15 articles) suggest significant cross-pollination between VRET and the motor rehabilitation applications of immersive tools. Technology-specialized journals, including Frontiers in Virtual Reality (14 articles) and Virtual Reality (13 articles), further illustrate the breadth of the research landscape by capturing hardware, software, and human factors dimensions alongside clinical outcome data.

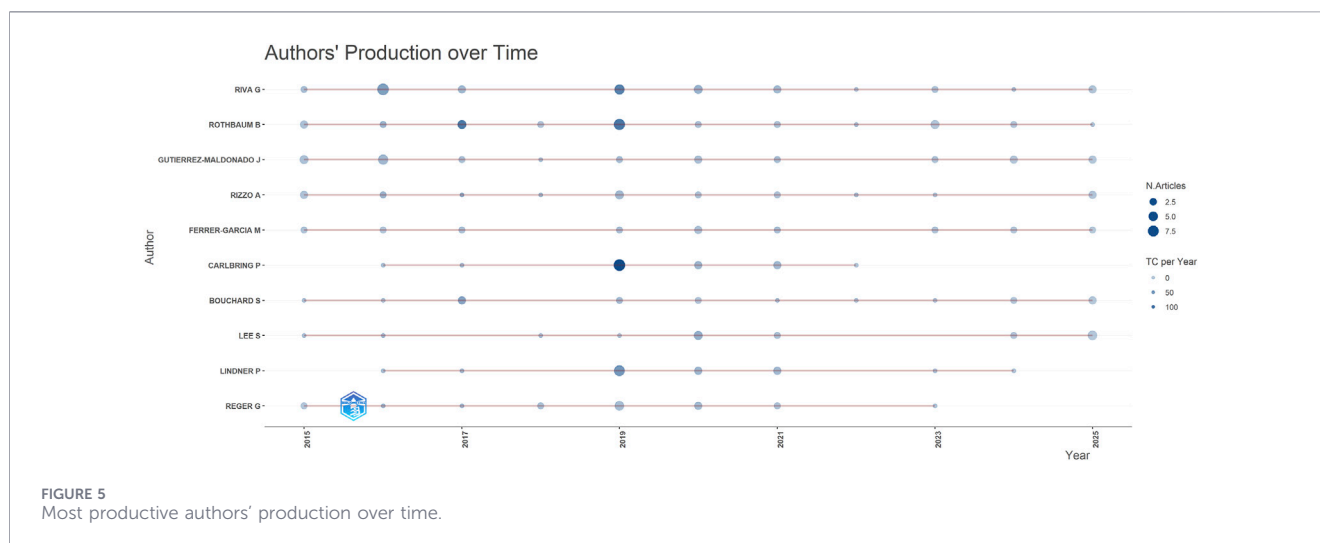
Emerging interdisciplinary venues, such as JMIR Mental Health (11 articles), Current Psychiatry Reports (11 articles), and Clinical Psychology and Psychotherapy (10 articles), show the technology's expanding footprint across both open-access digital platforms and traditional subscription-based journals. The Journal of Behavior Therapy and Experimental Psychiatry (12 articles) and the Journal of Affective Disorders (10 articles) further confirm that VRET research has achieved meaningful penetration into core behavior therapy and affective science venues, moving well beyond its origins in niche cybertherapy outlets. Collectively, the distribution of the merged dataset across 720 unique journals demonstrates the comprehensive coverage achieved by combining Scopus and Web of Science, effectively capturing the full clinical and technological spectrum of VRET research.

TABLE 4 Top publication sources.

Sources	Articles
Cyberpsychology, behavior, and social networking	32
Trials	30
Journal of medical internet research	29
International journal of environmental research and public health (IJERPH)	26
Journal of anxiety disorders	26
BMJ open	25
Frontiers in psychiatry	25
Journal of clinical medicine	24
PLOS ONE	21
Annual review of cybertherapy and telemedicine	18
Behaviour research and therapy	16
BMC psychiatry	15
Journal of neuroengineering and rehabilitation	15
Frontiers in psychology	14
Frontiers in virtual reality	14
Virtual reality	13
Journal of behavior therapy and experimental psychiatry	12
Psychological medicine	12
Current psychiatry reports	11
JMIR mental health	11
Medicine (United States)	11
Clinical psychology and psychotherapy	10
Journal of affective disorders	10
Psychiatry research	10

3.2 Author collaboration networks

The analysis of author productivity within the 1,583-article dataset highlights a concentrated level of research activity among a cohort of prolific scholars who have defined the intellectual trajectory of the VRET field (Figure 5; Table 5). Giuseppe Riva emerged as the most productive author with 34 articles, reflecting a sustained research program that spans the theoretical foundations of presence and embodiment, alongside clinical applications in eating disorders, body image disturbances, and anxiety. Barbara Rothbaum followed with 31 articles, representing the field's most consistent work on VRET for PTSD and military trauma, with a specific focus on the comparative effectiveness of VR *versus* traditional prolonged exposure protocols in veteran and active-duty populations. Additionally, José Gutiérrez-Maldonado contributed 28 articles, primarily addressing VRET applications for substance use and eating disorders, establishing the third most productive research trajectory in the dataset.



Patterns of author collaboration reveal a combination of individual productivity and tightly coordinated research networks. Skip Rizzo contributed 20 articles focused on clinical VR readiness and combat-related PTSD, frequently collaborating with Rothbaum and Reger to form a prominent North American military-clinical VRET research consortium; this group represents the most citation-impactful collaborative cluster identified. The collaborative structure of the field is further illustrated by Marta Ferrer-García (19 articles) and Per Carlbring (18 articles). Ferrer-García's output is closely integrated with that of Gutiérrez-Maldonado, reflecting a productive Barcelona-based research group specializing in cue-exposure and eating disorders. Conversely, Carlbring's work is tightly coupled with that of Per Lindner (17 articles), forming a Scandinavian research network focused on gamified and self-guided VRET for public speaking anxiety and specific phobias using consumer-grade hardware.

The remaining top-ranked authors, Stéphane Bouchard (17 articles), Greg Reger (17 articles), Sungkun Lee (17 articles), and Per Lindner (17 articles), further demonstrate the thematic diversity and geographic breadth of leading VRET scholarship. Bouchard's research concentrated on OCD and social anxiety disorder from a Canadian institutional base, while Reger's work extended the North American military PTSD cluster through rigorous comparative trial methodologies. The geographic distribution of the top ten authors, spanning Italy, the United States, Spain, Sweden, Canada, and South Korea, confirms that leadership in VRET research is internationally distributed across distinct thematic specializations. This global footprint suggests that the field is not concentrated within a single national infrastructure but is instead shaped by interdisciplinary and cross-cultural clinical demands.

The international co-authorship rate of 3.92%, calculated using fractional counting of institutional affiliations per article, is substantially below norms reported for clinical psychology (approximately 15%–20%) and digital health research (approximately 10%–15%). This low rate likely reflects a combination of factors: the specialist technical infrastructure required for VRET research limiting participation to well-

TABLE 5 Most productive authors and their number of articles.

Authors	Affiliation	Articles
Riva G	Università Cattolica, Italy	34
Rothbaum B	Emory University, USA	31
Gutierrez-Maldonado J	Universitat de Barcelona, Spain	28
Rizzo A	USC Institute, USA	20
Ferrer-Garcia M	Universitat de Barcelona, Spain	19
Carlbring P	Stockholm University, Sweden	18
Bouchard S	Université du Québec, Canada	17
Reger G	VA puget sound, USA	17
Lee S	Multiple affiliations, South Korea	17
Lindner P	Stockholm University, Sweden	17

resourced centers; the historically single-institution trial design culture of clinical psychology and psychiatry; and potential database affiliation disambiguation limitations that may undercount multi-country collaborations where author affiliations are incompletely recorded in Scopus and Web of Science metadata (Donthu et al., 2021).

3.3 Science mapping and co-occurrence analysis

The science mapping analysis of the 1,583-article dataset identified distinct thematic clusters within VRET research, encompassing clinical application domains, methodological frameworks, and participant characteristics. As shown in Figure 6, the keyword co-occurrence network revealed three interconnected clusters that reflect the multidimensional nature of VRET scholarship. Network analysis based on betweenness centrality metrics demonstrated that core VRET concepts function as the primary conceptual bridges linking these three thematic domains.

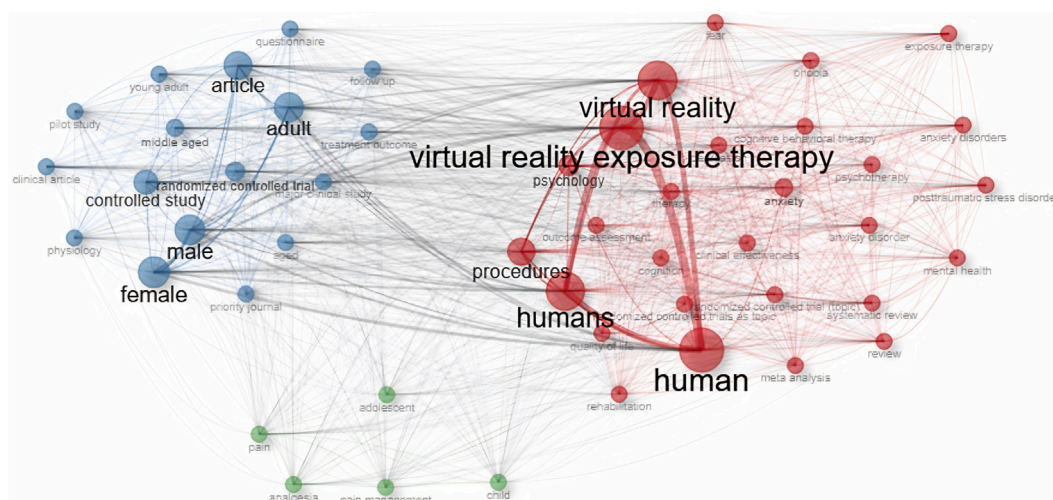


FIGURE 6
Keyword co-occurrence network.

Cluster 1 (Red nodes), centered on “virtual reality exposure therapy” and “virtual reality,” constitutes the largest thematic group and covers core clinical applications and their immediate therapeutic contexts. This cluster exhibited the highest betweenness centrality values across the network, with human (0.978), virtual reality exposure therapy (0.959), and virtual reality (0.892) serving as the three essential bridges connecting different research sub-domains.

Key nodes such as humans (0.679), procedures (0.280), anxiety (0.120), and psychology (0.119) indicate a strong integration between immersive technologies and established clinical psychology frameworks. In contrast, disorder-specific keywords, including posttraumatic stress disorder, phobia, cognitive behavioral therapy, and systematic review, showed lower centrality values. This suggests they function as terminal application nodes for specific clinical niches rather than broad conceptual bridges. The inclusion of meta analysis, RCT, and outcome assessment confirms that Cluster 1 represents the empirical clinical evidence base of VRET, where methodological rigor and disorder-specific measurement are the dominant concerns.

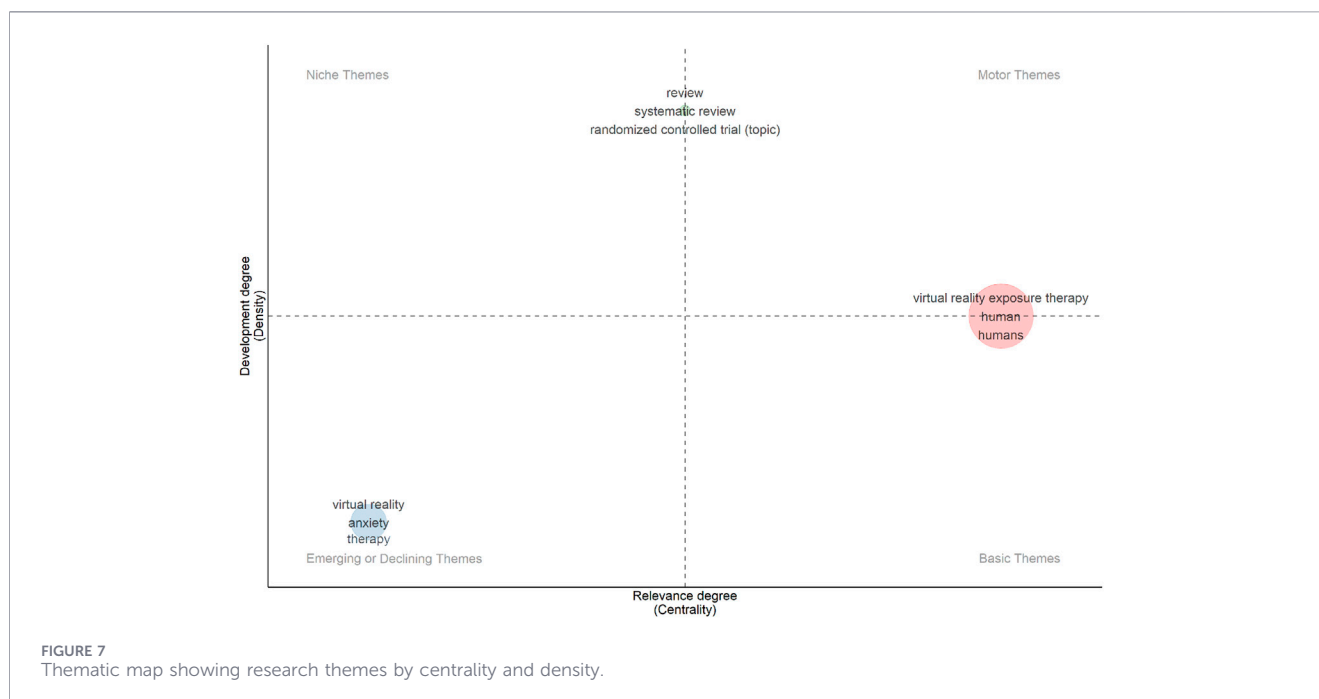
Cluster 2 (Blue nodes), centered on “female,” “male,” and “adult,” represents a methodological and participant characterization cluster. This group reflects the demographic and study design reporting conventions prevalent in VRET clinical trial literature. Substantial betweenness centrality was observed for adult (0.312), female (0.309), and male (0.271), highlighting their roles as bridging descriptors that connect clinical findings across diverse populations and designs. Keywords such as randomized controlled trial, controlled study, treatment outcome, and follow up demonstrate that this cluster captures the methodological infrastructure of the field, specifically the sampling and reporting standards, rather than its thematic content. Furthermore, the co-occurrence of physiology and pilot study suggests an emerging methodological strand that incorporates physiological outcome measures into early-phase clinical investigations.

Cluster 3 (Green nodes), centered on “pain,” “analgesia,” and “pain management,” identifies a clinically distinct but peripherally connected research stream addressing VR-based pain intervention, particularly in pediatric and adolescent populations. This is evidenced by the co-occurrence of child and adolescent within the cluster. Although betweenness centrality values for Cluster 3 were modest, ranging from 0.011 for pain management to 0.022 for adolescent, their separation from the core anxiety and PTSD literature of Cluster 1 indicates that VR-based pain management is a recognizable but partially isolated research strand. Its positioning suggests that while this research is indexed within the same bibliometric corpus, it operates with a distinct theoretical and clinical vocabulary, resulting in reduced connectivity with core VRET concepts.

3.4 Thematic map analysis

As shown in Figure 7, thematic map analysis offers a complementary perspective on the intellectual structure of the VRET field, categorized across two primary dimensions: relevance degree (centrality) and development degree (density). The current analysis delineates four distinct quadrants to categorize the developmental maturity of various research themes across the literature. The resulting pattern indicates a field where the core intervention concepts have attained high centrality, yet internal specialization remains uneven across different research streams.

Motor Themes (upper-right quadrant) were notably absent in this analysis. This finding suggests that the VRET field currently lacks research areas that simultaneously possess high internal cohesion (density) and robust external connections to other domains (centrality). The lack of motor themes is significant, as it indicates that while VRET research is well-established and expanding, no single thematic area has yet reached the dual status of being both a highly specialized research front and a central connector for the broader literature. Such a pattern is characteristic of a maturing field that has not yet consolidated around a single, dominant integrative paradigm.



Basic Themes (lower-right quadrant) contained the most central cluster of the study, with “virtual reality exposure therapy,” “human,” and “humans” identified as the core transversal concepts. Despite having relatively lower density, these themes exhibited the highest centrality values in the entire map. This confirms their role as the fundamental conceptual anchors that link multiple research streams without being confined to a single specialized niche. This positioning indicates that VRET as an intervention modality and its focus on human participants are mature, widely adopted foundations that serve as the primary connective tissue across disorder-specific, methodological, and population-focused research.

Niche Themes (upper-left quadrant) included “review,” “systematic review,” and “randomized controlled trial (topic),” representing specialized but peripherally connected methodological areas. These themes showed comparatively high internal development, reflecting a substantial and coherent body of VRET evidence synthesis and trial methodology, but limited centrality within the broader thematic network. This suggests that the scholarly sub-community focused on VRET trial methodology and evidence synthesis is well-developed and internally consistent, yet remains partially isolated from the applied clinical and technological dimensions of the field.

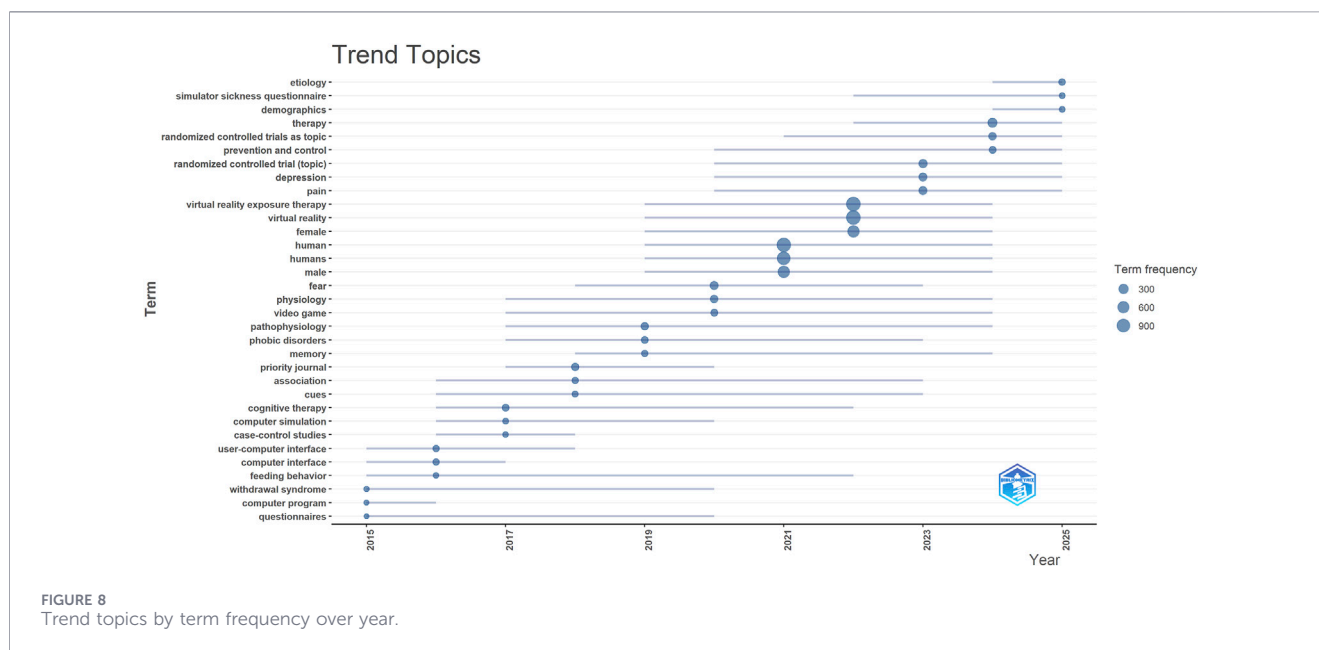
Emerging or Declining Themes (lower-left quadrant) covered “virtual reality,” “anxiety,” and “therapy,” all positioned with both low centrality and low density. The location of these seemingly foundational terms in this quadrant is a striking finding. It indicates that as standalone keywords, they either represent emerging conceptual directions that have not yet developed coherence, or more likely, declining indexing conventions. These broader terms appear to be superseded by the more precise descriptor “virtual reality exposure therapy,” which has successfully migrated into the Basic Themes quadrant. This terminological transition from general terms like virtual reality

and anxiety toward the specific virtual reality exposure therapy reflects the conceptual maturation and increasing disciplinary precision of the VRET research community throughout the 2015–2025 period.

3.5 Trend topic analysis

The analysis of trending topics illustrates the temporal progression of keyword usage from 2015 to 2025, highlighting distinct developmental phases within the VRET literature (Figure 8). The initial period (Q1 and median 2015–2016) was characterized by terms such as withdrawal syndrome, computer interface, user-computer interface, and computer simulation. This reflects the field’s early technical and addiction-centric focus, where research was primarily concerned with VR delivery infrastructure and substance-related cue exposure. Furthermore, the early prominence of feeding behavior (median 2016) confirms that eating disorder applications were among the first established clinical domains, aligning with the foundational work of Riva et al. (2019) noted in the productivity analysis.

A subsequent transitional phase (median 2017–2020) saw the consolidation of core clinical and methodological terminology. During this time, cognitive therapy (frequency: 70, median: 2017), phobic disorders (frequency: 70, median: 2019), fear (frequency: 161, median: 2020), and physiology (frequency: 129, median: 2020) became increasingly central. The rise of the term video game (frequency: 61, median: 2020) suggests the growing impact of gamification and self-guided delivery models, particularly for phobia treatments using consumer hardware. The terms human (frequency: 1,085, median: 2021) and humans (frequency: 893, median: 2021) reached their median frequency during this interval, reflecting the surge in human-participant clinical trials that began in 2019.



The most recent phase (median 2022–2025) is defined by the dominance of virtual reality exposure therapy (frequency: 1,142, median: 2022) and virtual reality (frequency: 1,140, median: 2022) as the most frequent descriptors. This confirms the terminological stabilization identified in the thematic map. Significantly, several clinical terms reached their median frequency only after 2022, including depression (frequency: 169, median: 2023), pain (frequency: 153, median: 2023), randomized controlled trial (frequency: 189, median: 2023), and therapy (frequency: 284, median: 2024). This indicates that the most active research frontiers currently involve rigorous trial methodologies and the expansion of VRET into pain and depression management. Finally, the emergence of terms like etiology (Q1: 2024), demographics (Q1: 2024), and simulator sickness questionnaire (median: 2025) suggests three nascent directions: the mechanistic study of disorder origins, demographic moderator analysis, and the standardisation of cybersickness measurement as a key safety outcome.

4 Discussion

The following discussion combines the results of the qualitative review of 40 landmark studies with the structural bibliometric data. This provides an interpretation of the clinical evidence for VRET, how technology is being integrated, the underlying therapeutic mechanisms, and the challenges of putting these systems into practice.

Sections 4.1 through 4.4 examine the qualitative findings by clinical area and technological type, linking these results to the broader bibliometric trends identified in Section 3. Section 4.5 then uses this combined analysis to point out gaps in current research and suggest future directions. The findings presented here were gathered using the structured framework mentioned in Section 2.4 and are compared against existing literature to provide a meaningful discussion rather than just a list of results.

4.1 Clinical application domains in VRET

The qualitative analysis of the 40 studies primarily reveals seven clinical application domains where VRET demonstrates transformative therapeutic potential. These domains represent specific areas of application with varying levels of empirical maturation, ranging from well-established evidence bases supported by meta-analytic confirmation to emerging applications requiring further controlled investigation.

4.1.1 Specific phobias

Specific phobias constitute the most empirically mature domain within the VRET literature, supported by a vast body of randomized controlled trials (RCTs) covering acrophobia, arachnophobia, aviophobia, and needle-related phobias. Research in acrophobia has yielded particularly strong evidence; notably, [Freeman et al. \(2017\)](#) demonstrated that automated, gamified virtual height environments can achieve significant fear reduction without a therapist's presence, challenging traditional requirements for direct clinical supervision. Automated protocols have also proven effective for arachnophobia, with [Miloff et al. \(2019\)](#) reporting that single-session VRET is non-inferior to traditional *in-vivo* treatment. Similarly, [Lindner et al. \(2019\)](#) found that self-led VRET using consumer hardware provides fear reduction comparable to therapist-led interventions. A meta-analysis by [Carl et al. \(2019\)](#) confirmed large overall effect sizes ($g = 0.90$), with the most consistent results seen in aviophobia and acrophobia. Despite their clinical prevalence, blood-injury-injection phobias remain underrepresented in the RCT literature, even though VR offers distinct advantages for standardising medical stimuli.

4.1.2 Social anxiety disorder

Social anxiety disorder is the second major application domain, utilizing virtual environments to simulate public speaking and social

interactions that are difficult to replicate reliably in real-world settings. Bouchard et al. (2017) established VRET as a credible first-line treatment, showing that it produces outcomes equivalent to *in-vivo* CBT. Direct head-to-head comparisons by Kampmann et al. (2016a) further confirmed this non-inferiority. Additionally, Lindner et al. (2017) highlighted the ecological validity of using consumer-grade hardware to simulate complex social scenarios like job interviews or audience presentations without the logistical burden of hiring confederates. Recent refinements in this area include avatar interaction paradigms, which allow for the precise, parametric manipulation of audience size and social threat cues (Geraets et al., 2021).

4.1.3 Post-traumatic stress disorder (PTSD)

PTSD has the longest clinical history in the field, primarily driven by military-focused programs. For instance, Reger et al. (2016) demonstrated in a landmark study that VRET is as effective as imaginal prolonged exposure for active-duty soldiers, offering specific advantages for patients who struggle to engage vividly with mental imagery. While military applications are most prominent, civilian trauma research, including sexual trauma and disaster-related PTSD, has expanded throughout the review period. Rothbaum and Rothbaum (2025) demonstrated the feasibility of VRET for military sexual trauma, and a meta-analysis by Kothgassner et al. (2019) confirmed moderate-to-large effect sizes across both military and civilian populations. However, definitive comparative conclusions are still limited by heterogeneity in trauma types and hardware platforms.

4.1.4 Panic disorder and agoraphobia

Panic disorder and agoraphobia represent a critical but under-investigated domain. Unlike phobias, these conditions often require interoceptive exposure, targeting internal bodily sensations, which necessitates innovative environmental design. Wechsler et al. (2019) identified that while VRET successfully uses public transport and shopping center scenarios for situational exposure, large-scale RCTs comparing VRET to standard interoceptive protocols are still lacking. Furthermore, Emmelkamp and Meyerbröker (2021) observed that therapist-guided VRET tends to outperform self-directed models in this population, suggesting that the complexity of managing interoceptive cues may require higher levels of clinical oversight.

4.1.5 Obsessive-compulsive disorder

OCD is a compelling emerging domain where virtual environments provide a level of controllability for triggers (such as contamination or symmetry) that traditional *in-vivo* exposure and response prevention (ERP) cannot match. Preliminary evidence from Emmelkamp and Meyerbröker (2021) indicates that virtual scenarios can successfully activate obsessional distress to support ERP practice. However, the lack of large-scale RCTs remains a significant evidence gap, making OCD one of the least developed clinical areas in the current VRET literature.

4.1.6 Eating disorders and body image disturbance

In the treatment of eating disorders, VRET leverages the unique ability to manipulate avatar representations to target distorted body schemas. Riva and colleagues established the foundation for this domain, showing that VR cue exposure for food and body-related triggers significantly reduces binge eating frequency and body dissatisfaction compared to standard CBT (Riva et al., 2019; Chirico and Gaggioli, 2019). Gutiérrez-Maldonado et al. (2016) further demonstrated that “body ownership illusions” through avatars can reduce fear of weight gain and attentional biases. These findings are supported by neuropsychological evidence from Serino et al. (2016), which confirmed that virtual “body swapping” can measurably alter allocentric body memory.

4.1.7 Emerging and underexplored clinical targets

The synthesis identified several nascent but promising targets for VRET. Chronic and procedural pain management is currently the most advanced emerging domain; Spiegel et al. (2019) demonstrated acute pain reduction through VR distraction, while Eijlers et al. (2019) confirmed its efficacy in reducing medical anxiety across pediatric and adult contexts. Substance use disorder research, pioneered by Gutiérrez-Maldonado, has shown that VR cue exposure can improve treatment retention and reduce cravings for alcohol use disorder (Boeldt et al., 2019). Other priority areas for future research include social skills training for autism, adjunct applications for depression, and anxiety interventions for geriatric populations, all of which currently lack sufficient controlled trial data (Emmelkamp and Meyerbröker, 2021; Wiebe et al., 2022).

4.2 Technology integration patterns in VRET

The analysis uncovered intricate configurations of technological integration that extend VRET capabilities well beyond simple stimulus presentation, encompassing hardware platform evolution, artificial intelligence (AI) integration, digital twin frameworks, closed-loop biofeedback systems, and telehealth delivery infrastructures that collectively define the current technological frontier of immersive therapeutic intervention.

4.2.1 Hardware platforms and their clinical implications

The choice of hardware platform is a critical implementation decision in VRET, as it involves balancing immersion quality, portability, cost, and technical complexity, all of which affect therapeutic efficacy and deployment feasibility. Tethered head-mounted displays (HMDs) linked to high-performance computers provide superior rendering and tracking precision. These systems are essential for intensive scenarios like combat trauma re-experiencing and complex social interactions, though their high infrastructural costs often limit them to specialized centers (Rizzo and Koenig, 2017; Maples-Keller et al., 2017). Conversely, standalone wireless headsets have transformed the field. Donker et al. (2019) established that consumer-grade standalone hardware could produce acrophobia treatment

outcomes equivalent to laboratory-grade systems, proving the viability of portable platforms for specific phobias.

While CAVE systems are now less common for routine use, they remain advantageous for protocols requiring full-body movement or multi-participant interactions, such as group-based social anxiety therapy (Emmelkamp and Meyerbröker, 2021). Mobile VR (smartphone-based) offers the highest accessibility but presents clinical drawbacks, including a narrower field of view and lower refresh rates, which can increase cybersickness and diminish patient tolerability (Carl et al., 2019; Wiebe et al., 2022). The current hardware frontier involves integrating eye-tracking and physiological sensors like heart rate and EEG monitors directly into HMDs to enable adaptive and biofeedback-driven therapy (Salkevičius et al., 2019; Philippe et al., 2022).

4.2.2 AI and adaptive exposure systems

The integration of AI is perhaps the most transformative trend in VRET, allowing for a level of dynamic individualization that standard protocols cannot reach. Real-time physiological monitoring systems, measuring heart rate variability, galvanic skin response, and respiration, are now used to automate scenario difficulty. This ensures that exposure remains within an optimal “therapeutic window” of fear activation without overwhelming the patient (Salkevičius et al., 2019; Wiebe et al., 2022). Machine learning models can now estimate fear levels in real-time, allowing systems to anticipate and respond to an individual’s anxiety trajectory rather than simply reacting to physiological spikes (Philippe et al., 2022; Usmani et al., 2022). While fully automated, AI-driven hierarchy generation based on reinforcement learning remains in the proof-of-concept stage, it represents the logical future of personalised VRET (Geraets et al., 2021).

4.2.3 Digital twin integration

Digital twin technology is an emerging paradigm that synchronizes behavioral, physiological, and clinical data streams into a continuously updated computational model of the patient. Philippe et al. (2022) identified digital twins as a strategic direction for clinical VR, noting their ability to predict optimal exposure progression with a precision that standardised protocols lack. By using real-time sensor data to update the “twin” during a session, clinicians can make data-driven decisions based on objective habituation trajectories rather than subjective self-reports alone (Usmani et al., 2022; Wiebe et al., 2022). Although fully realized digital twin VRET is currently aspirational, the convergence of wearables, cloud computing, and machine learning makes this a credible near-term research priority (Geraets et al., 2021).

4.2.4 Biofeedback closed-loop systems

Closed-loop VRET systems utilize biofeedback to operationalize fear activation through objective metrics. Integration of heart rate, galvanic skin response, and EEG allows platforms to use these signals as both outcome measures and active control inputs. Salkevičius et al. (2019) demonstrated that fusing multiple physiological signals leads to more accurate anxiety classification than single-modality approaches. These systems prevent “under-

engagement” (where lack of fear limits learning) and “overload” (where excessive distress leads to dropout) (Carl et al., 2019; Emmelkamp and Meyerbröker, 2021). Technically advanced neurofeedback applications, where EEG markers drive real-time environmental changes, show promise for enhancing the consolidation of extinction learning, though this approach requires more extensive clinical validation (Philippe et al., 2022).

4.2.5 Telehealth and remote VRET delivery

Telehealth-based VRET has evolved from a logistical alternative into an empirically validated delivery model. Cloud-based infrastructures now support remote scenario delivery and session synchronization, removing geographic and financial barriers to care (Horigome et al., 2020; Smith et al., 2020). Freeman et al. (2022) confirmed in a large-scale RCT that remotely supervised VRET for height phobia yielded improvements comparable to clinic-based delivery. Furthermore, studies by Donker et al. (2019) and Miloff et al. (2019) proved that fully self-guided, home-deployed protocols can be highly effective. This suggests that the remote model is not just a compromise, but a viable pathway that actively reduces barriers for patients whose anxiety or avoidance behaviors make clinic attendance difficult (Emmelkamp et al., 2020; Wiebe et al., 2022).

4.3 Therapeutic mechanisms and key outcome variables

The qualitative synthesis revealed that VRET operates through several interacting therapeutic mechanisms that are both theoretically grounded in established exposure therapy frameworks and uniquely amplified by the properties of immersive virtual environments. Understanding these mechanisms and the outcome variables used to measure them is essential for interpreting the heterogeneity of effect sizes observed across clinical application domains and for guiding the methodological standardisation that the field currently requires.

4.3.1 Presence and immersion as mediators of therapeutic outcome

The concept of presence, the subjective feeling of “being there” within a virtual environment, is recognized as the primary psychological mediator connecting immersive technology to clinical success. Research indicates that higher presence is associated with increased fear activation, authentic emotional processing, and more robust extinction learning across PTSD and anxiety applications. Riva et al. (2019) provide a comprehensive theoretical framework for this, suggesting that VR presence engages the same body memory and emotional systems used during real-world threats. This allows for genuine neurobiological extinction rather than purely cognitive fear reduction, which is particularly beneficial for patients with weak mental imagery skills. Furthermore, Botella et al. (2017) established that presence ratings effectively predict anxiety activation and subsequent fear reduction, proving it is a clinically significant process variable. While “immersion” refers to the objective quality of the hardware (e.g., resolution and tracking), it is distinct from presence; individual factors like

absorption and dissociative tendencies moderate how effectively a patient converts technological immersion into a psychological sense of presence (Maples-Keller et al., 2017; Carl et al., 2019).

4.3.2 Fear activation and extinction in virtual environments

Exposure-based extinction learning requires sufficient fear activation to be effective. Virtual environments provide unparalleled parametric control over the intensity and duration of stimuli, allowing for more precise management of fear than traditional imaginal or *in-vivo* methods. A systematic review by Morina et al. (2015) confirmed that VRET triggers biologically authentic fear responses, evidenced by heart rate elevation and cortisol reactivity, rather than just cognitive acknowledgment of a threat. Modern VRET research increasingly applies the “inhibitory learning model,” which posits that exposure creates new safety associations that inhibit original fear memories. Experts suggest that VR-specific features, such as systematic context switching and the deliberate violation of threat expectancies, may enhance this inhibitory learning beyond what standard protocols achieve (Wechsler et al., 2019; Emmelkamp and Meyerbröker, 2021). Specifically, VR allows for the organized presentation of feared stimuli in a setting where a patient’s expected negative outcomes clearly do not happen. This provides a direct experience that disproves those fears, helping the patient develop more accurate safety-related thoughts and supporting the process of inhibitory learning (Scheveneels et al., 2016).

4.3.3 Transfer of treatment gains to real-world contexts

The ultimate measure of VRET’s utility is whether fear reduction achieved in a headset transfers to the real world. Meta-analyses have consistently supported this generalization, with Carl et al. (2019) showing that VRET-induced gains are equivalent to those of *in-vivo* exposure when measured through real-world behavioral tasks. This success is largely attributed to the ecological validity of virtual scenarios that share enough perceptual features with reality to support memory generalization (Morina et al., 2015). However, transfer efficacy can vary by population; for example, PTSD applications sometimes show stronger generalization than specific phobias, likely due to differences in how trauma-related *versus* phobia-related memories are stored (Emmelkamp and Meyerbröker, 2021). This underscores the need for VRET trials to include real-world behavioral assessments alongside traditional questionnaires.

4.3.4 Commonly used outcome instruments

The VRET literature utilizes a wide range of measurement tools, reflecting the field’s cross-disciplinary nature. Across the 40 studies analyzed, Subjective Units of Distress Scale (SUDS) ratings were the most common measurement used during sessions. Most of the reviewed trials used these ratings to track fear levels as they happened. This finding matches earlier research by Carl et al. (2019). It also found that SUDS was the primary way researchers measured fear during VRET sessions. For pre- and post-treatment

assessment, researchers rely on validated disorder-specific scales, such as the PTSD Checklist (PCL), the Liebowitz Social Anxiety Scale (LSAS), and various questionnaires for heights and spiders (Rothbaum and Rothbaum, 2025; Miloff et al., 2019). While presence is often measured using the Presence Questionnaire or the Igroup Presence Questionnaire (IPQ), it is still omitted in a significant portion of studies. This remains a gap in the literature, as it prevents a full understanding of how presence mediates clinical outcomes (Botella et al., 2017).

4.3.5 Physiological vs. subjective fear measurement

A significant debate in VRET research concerns the dissociation between physiological and subjective indicators of fear. Such objective measures as heart rate variability, galvanic skin response, and facial EMG provide continuous data that is resistant to social desirability bias or retrospective distortion. Rothbaum and Rothbaum (2025) found that physiological changes during exposure predicted long-term PTSD symptom reduction independently of subjective reports. Conversely, subjective measures (like SUDS) capture the phenomenological experience of the patient, which is often the most meaningful clinical outcome. Because cognitive and autonomic improvements can occur independently, the current gold standard is a multimodal assessment approach that combines self-report, physiological monitoring, and behavioral tasks (Wiebe et al., 2022; Philippe et al., 2022).

4.4 Challenges and limitations to VRET implementation

The challenges and barriers discussed in this section come from the combined evidence of the qualitative synthesis. This is supported by broader literature when specific implementation details were not covered in that primary group. Statements about clinical safety, how often cybersickness occurs, and the necessary skills for therapists are based on findings reported in several of the included studies. These points are kept separate from any speculative guesses throughout the text.

Despite the substantial and growing evidence base supporting VRET efficacy across multiple clinical domains, the translation of laboratory-validated protocols into routine clinical practice remains constrained by a constellation of challenges spanning therapeutic, technical, and regulatory dimensions. The qualitative synthesis identified these barriers as the primary factors limiting the scalability and accessibility of VRET beyond specialist research centers, and their systematic resolution constitutes one of the field’s most pressing priorities for the coming decade.

4.4.1 Clinical challenges and ethical considerations

Cybersickness, a combination of nausea, disorientation, and postural instability caused by sensory conflict, is the most prominent adverse effect of VRET. Prevalence in clinical populations is estimated between 10% and 40%, influenced by hardware specifications, session length, and individual sensitivity (Carl et al., 2019; Wiebe et al., 2022). The clinical impact of

cybersickness is significant; if a patient terminates a session due to nausea, it may act as an avoidance behavior that reinforces rather than extinguishes fear. Furthermore, repeated aversive experiences risk conditioning a negative association with the technology, potentially hindering future engagement (Emmelkamp and Meyerbröcker, 2021; Philippe et al., 2022). Best practices to mitigate these risks include gradual habituation, optimized refresh rates, and strict session limits, though the use of standardised tools like the Simulator Sickness Questionnaire remains inconsistent in published trials (Wiebe et al., 2022).

In trauma-focused VRET, the risk of retraumatization presents a serious ethical challenge. High-fidelity environments for combat PTSD or sexual trauma may trigger acute distress that exceeds a patient's regulatory capacity if exposure parameters are poorly calibrated (Reger et al., 2016; Rothbaum and Rothbaum, 2025). Rizzo and Koenig (2017) argue that rigorous contraindication screening, excluding those with active psychosis, severe dissociation, or acute suicidality, is vital for safety, yet many protocols lack formal selection criteria. Additionally, the requirement for therapists to be proficient in both clinical methodology and technical VR operation remains a major barrier that is rarely addressed in standard clinical training (Maples-Keller et al., 2017; Emmelkamp and Meyerbröcker, 2021). Ethical delivery also requires informed consent processes that prepare patients for the unique experiential intensity of immersive re-experiencing (Riva et al., 2019).

Ethical and safety concerns in VRET go far beyond managing cybersickness; they also involve the creation of robust data privacy and governance systems to protect the highly sensitive physiological and trauma-related information collected during therapy. Clinical protocols must include specific safety measures for handling potential retraumatization or acute dissociative episodes that can occur in high-fidelity virtual environments. Furthermore, because immersive re-experiencing is qualitatively different from traditional exposure therapy, it creates unique informed consent requirements.

As VRET technology evolves to include AI-driven personalisation, cloud storage, and telehealth, meeting regulatory standards such as GDPR and HIPAA must be viewed as a fundamental requirement for implementation rather than an afterthought. Additionally, the use of AI-based therapist agents introduces new ethical dilemmas regarding how to obtain informed consent for clinical decisions made by software rather than human supervisors—an issue the field has yet to resolve systematically (Emmelkamp and Meyerbröcker, 2021; Philippe et al., 2022).

4.4.2 Technical barriers

Hardware costs continue to be a structural barrier to VRET dissemination. High-end tethered systems and physiological monitors represent capital expenses that often exceed the budgets of community health centers and primary care services where the need is greatest (Carl et al., 2019; Donker et al., 2019). While standalone headsets have lowered costs, they often involve trade-offs in rendering fidelity and tracking precision, which may limit their use in complex cases requiring highly individualized environments (Emmelkamp and Meyerbröcker, 2021).

Furthermore, the VRET software landscape is fragmented across proprietary research tools and commercial applications, making it difficult to replicate or compare results across different sites (Philippe et al., 2022; Wiebe et al., 2022). Interoperability also remains an issue, as many VR platforms do not integrate with electronic health records or existing telehealth infrastructure, leading to data fragmentation and increased documentation burdens (Usmani et al., 2022). Finally, the sensitive nature of mental health and physiological data necessitates regulatory-grade security frameworks that many current platforms have yet to fully implement (Wiebe et al., 2022; Geraets et al., 2021).

4.4.3 Regulatory and implementation barriers

The lack of standardised clinical guidelines is perhaps the most significant systemic barrier to adoption. Currently, there is no authoritative consensus on patient selection, competency requirements, or safety procedures, which leaves clinicians and insurance providers hesitant to embrace VRET in routine practice (Emmelkamp and Meyerbröcker, 2021; Rizzo and Koenig, 2017). The development of professional-body-endorsed guidelines is considered a prerequisite for VRET to transition from a specialist research tool to a mainstream service.

Financial sustainability is further hampered by a lack of VRET-specific billing codes and reimbursement policies, making routine delivery economically unfeasible without research grants or subsidies (Maples-Keller et al., 2017). Additionally, the regulatory pathway for VRET as a “digital therapeutic” remains poorly defined under FDA and CE frameworks. Depending on their classification, as medical devices, adjunct tools, or decision support systems, platforms face vastly different evidence requirements and liability frameworks (Philippe et al., 2022; Wiebe et al., 2022). Finally, general clinician resistance to adopting new technology remains a persistent, though addressable, hurdle to widespread implementation.

The successful application of VRET in low- and middle-income countries (LMICs) depends on more than just lowering the price of equipment. Achieving fair access requires virtual content that is culturally relevant, exposure hierarchies tailored to local norms, and treatment models adapted for use by non-specialist health workers. They are the areas currently overlooked in the literature. Furthermore, the structural needs of adaptive VRET, such as consistent internet access and technical support, remain significant hurdles that affordable headsets alone cannot fix. Future research must focus on collaborative co-design with local clinical and community leaders to create VRET programs specifically for these environments, rather than simply importing protocols designed for high-income nations (Carl et al., 2019; Donker et al., 2019).

4.5 Research gaps and future implications

This review identified three linked research gaps and future priorities that set the agenda for the next phase of VRET study. These findings have direct meaning for doctors, researchers, and tech developers as the field moves from specialized research into everyday clinical use.

Even with the huge increase in VRET publications from 2015 to 2025, the actual evidence is still limited because most studies are small-scale trials with follow-up periods that rarely last longer than 6 months. Most of the RCTs analyzed in the qualitative review had fewer than 100 participants. This size is too small to prove how long VRET-based learning lasts, find out what keeps the treatment working over time, or see how different patients respond based on how severe their condition is (Carl et al., 2019; Emmelkamp and Meyerbröker, 2021). For clinicians, this means they cannot yet give patients long-term recovery predictions with the same confidence they have for short-term results. Future trials should make 12-month follow-up checks and larger groups of participants a standard requirement. This would allow for better analysis based on the severity of the disorder, the type of hardware used, and how the therapy was delivered.

The variety of different measurement tools used in published VRET studies is a major methodological hurdle. This inconsistency prevents the precise data grouping needed to create official clinical guidelines and makes it difficult for doctors to compare results across different trials or disorders (Wiebe et al., 2022).

The field quickly needs a agreed-upon “core outcome set” for VRET. This would list mandatory areas to measure, such as how much a patient’s fear decreases, changes in avoidant behavior, the feeling of “being there,” physical reactions, and overall quality of life. These measures should apply to all types of disorders and ways the therapy is delivered.

For researchers, using a standardised framework like this when designing trials would make it much easier to combine data in future studies. For doctors and healthcare providers, the most important step for moving VRET into regular use is the creation of specific clinical practice guidelines. These guidelines should be officially backed by professional psychology and psychiatry organizations to ensure the technology is used confidently outside of specialized research centers.

The current research on VRET is mostly focused on adults in wealthy, specialized medical centers. This leaves children, the elderly, and people in low-resource areas as underserved groups. We still do not fully understand how well these populations tolerate VRET, what cultural changes are needed, or how practical it is to implement the therapy in those settings.

Using VRET for children is a strong idea because gamified virtual worlds can keep younger patients engaged, but there are still very few large-scale trials for this age group (Lindner et al., 2019). Older adults face different challenges, such as a higher risk of cybersickness, less familiarity with the technology, and age-related sensory issues. These factors require specially designed treatment plans that the current research has not yet addressed.

For researchers, the priority should be forming partnerships with underrepresented communities, including healthcare providers in lower-income countries, pediatric specialists, and geriatric psychiatrists. This would allow for the creation of VRET programs that fit the specific context rather than just copying methods used for adults in wealthy nations. For technology developers, the main goals for global fairness should be creating affordable, standalone hardware with simple interfaces, culturally relevant content, and delivery models that can be used by healthcare workers who are not specialists.

The integration of AI is the next big step for VRET, affecting both how therapy is delivered and how it is scientifically proven. In the short term, the most exciting opportunity lies in AI-driven personalised systems. These use “reinforcement learning” to change virtual content on the fly, monitor a patient’s physical stress levels in real-time to adjust difficulty, and create personalised avatars. However, before these can be used regularly, they need to be tested in head-to-head trials against traditional, therapist-led programs to ensure they are safe and effective (Philippe et al., 2022; Bergsnev and Sánchez Laws, 2026). Looking further ahead, the “next frontier” is Digital Twin integration. This involves creating a continuous digital model of a patient that tracks their clinical, physical, and behavioral data over time to suggest exactly how their treatment should progress.

The lack of health economic evaluations is arguably the most urgent practical gap in the field. Without clear evidence of cost-effectiveness, it is difficult for insurance providers and healthcare systems to make informed decisions about reimbursement or service priorities. Currently, almost no published studies provide the specific financial data, such as incremental cost-effectiveness ratios or quality-adjusted life year (QALY) estimates, needed for VRET to compete for funding against traditional medications or standard talk therapies (Donker et al., 2019; Carl et al., 2019).

To wrap things up, achieving these priorities requires a shift toward interdisciplinary collaboration. We need a framework that brings together clinical psychologists, psychiatrists, software engineers, hardware developers, and AI researchers into shared programs with synchronized timelines. Nowadays, these groups often work in “silos.” Technological breakthroughs in VR and AI frequently happen without clinical input, while clinical trials often use whatever tech is available without optimizing it for therapy. This has led to a gap where what the technology can do and what the clinical evidence proves are often misaligned (Emmelkamp and Meyerbröker, 2021; Philippe et al., 2022).

Recent investigations highlight a shift toward more sophisticated, technology-enhanced interventions that address long-standing limitations in the field. For instance (Bergsnev and Sánchez Laws, 2026), demonstrate the transformative potential of AI in automating therapeutic adjustments, while (de Haart et al., 2026) explore how augmenting virtual environments with real-time feedback can enhance patient engagement and treatment efficacy. Complementing these technological strides (Nedungadi et al., 2025), provide critical insights into the learning mechanisms underlying successful virtual exposure, offering a clearer blueprint for optimizing clinical protocols. Furthermore, the work of (Medeiros et al., 2026) in mapping the current landscape of VRET research underscores the necessity of standardising these emerging tools to ensure they can be effectively scaled across diverse clinical populations. Together, these studies represent a necessary move toward a more personalised, data-driven framework for virtual reality-based therapy.

4.6 Study limitations

This analysis is subject to several limitations regarding its scope and coverage. Although the dual-database approach ensured high-quality data, the exclusion of other databases may have resulted in the absence of relevant VRET research published in more targeted

clinical psychology journals, psychiatric conference proceedings, or newer digital health periodicals not yet fully indexed by these platforms. Furthermore, the decision to restrict the search to English-language publications may have limited the geographic and cultural breadth of the data, particularly in light of the significant VRET research output from non-Anglophone regions identified in the collaboration network analysis.

The qualitative synthesis utilized a citation-based selection method, which naturally favors older, established publications with more time to accumulate citations. Consequently, while the quantitative bibliometric analysis included 281 articles from 2025, none of these reached the citation threshold for qualitative review. This means that highly recent and potentially influential contributions regarding AI integration, digital twin frameworks, and telehealth delivery may be underrepresented in the clinical evidence synthesis. This methodological approach facilitates a dual focus: the qualitative synthesis examines the established intellectual structure of the domain, whereas the quantitative analysis serves as the essential instrument for capturing the latest bibliometric shifts and early-stage frontiers.

Additionally, inherent limitations in author disambiguation, common in bibliometric studies relying on surname and initial matching, may have introduced minor inaccuracies in productivity and collaboration metrics, especially for common surnames shared by multiple researchers. Finally, the rapid pace of innovation in VR hardware and software means that technical constraints or implementation hurdles identified in earlier studies within the 2015–2025 window may not accurately reflect current state-of-the-art capabilities. As the evidence base expands, continuous monitoring of the evolution in consumer and clinical VR infrastructure will be essential to maintain an accurate understanding of the field.

5 Conclusion

This systematic review and bibliometric study fulfill the research objectives by offering an extensive quantitative and qualitative evaluation of Virtual Reality Exposure Therapy (VRET). By utilizing a robust multi-database validation strategy, the study merged 1,551 articles from Scopus and 264 from Web of Science, resulting in a final corpus of 1,583 unique publications from 2015 to 2025. The 12.8% overlap between these databases confirms a high degree of cross-validation and complementary coverage of the field's most influential research.

The bibliometric data indicates a period of sustained expansion, with annual publications rising 3.7-fold from 76 in 2015 to 281 in 2025. This 13.97% annual growth rate positions VRET as a rapidly consolidating pillar of clinical psychology and digital health. While the analysis identified a core group of prolific experts, most notably Riva (34 articles), Rothbaum (31 articles), and Gutiérrez-Maldonado (28 articles), the international co-authorship rate remains low at 3.92%. This suggests that despite the field's global reach, significant potential for cross-national research collaboration remains untapped.

A qualitative synthesis of 40 impactful studies established that specific phobias, social anxiety, PTSD, panic disorder, OCD, and eating disorders are the primary clinical domains for VRET. The evidence for these applications ranges from robust meta-analytic support (phobias and PTSD) to emerging feasibility data (OCD). On

the technological front, the field has seen a sophisticated convergence of hardware platforms, AI-driven adaptive protocols, closed-loop biofeedback systems, and telehealth infrastructures, creating a versatile framework for both in-clinic and remote treatment delivery.

The intersection of AI, Digital Twin frameworks, and immersive environments marks the next major phase of VRET development. This evolution promises to shift the field from rigid, protocol-based exposure toward genuinely individualized, physiologically responsive systems that adapt in real-time. Realizing this potential will require deep interdisciplinary integration, bringing together psychologists, psychiatrists, software engineers, and AI researchers to align technical innovation with clinical validation.

To move VRET from a specialized research tool to a mainstream clinical service, the field must prioritize the standardisation of clinical protocols, outcome measures, and regulatory pathways. Currently, the lack of specific clinical practice guidelines, insurance reimbursement frameworks, and formal health technology assessments serves as the primary barrier to equitable access. Resolving these structural issues requires coordinated efforts from professional bodies, regulatory agencies, and healthcare payers.

For clinicians, the evidence supports the confident use of VRET for established applications like specific phobias, social anxiety disorder, and combat-related PTSD. However, safe and effective delivery requires implementing structured screenings for cybersickness, assessing contraindications, and following clear pathways for professional competency development.

For researchers, the main priorities include conducting large-scale RCTs with long-term follow-up and establishing standardised core outcome sets. It is also critical to use neuroimaging to validate how VR-induced extinction learning works in the brain. Most importantly, researchers must perform prospective economic evaluations that include healthcare utilization modeling and quality-adjusted life year estimates. This data is essential for convincing payers to transition VRET from an experimental innovation to a reimbursed clinical service.

For technology developers, the research points to a specific design mandate. Future systems should be built on affordable, standalone hardware that includes integrated physiological sensors and interoperable data infrastructures. These systems should also feature ethically governed, AI-driven scenario engines and personalised avatar systems that have been validated against clinical gold standards. Together, these elements form the foundation for the next-generation of accessible, personalised, and empirically accountable VRET.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

OEC: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review and editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. During the preparation of this work, the authors used Claude Sonnet 4.6 for writing assistance and for

grammar, spelling, and style review. The author declares that they have reviewed and edited the final output as needed and take full responsibility for the content of the published article.

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