
Virtual Reality Exposure Therapy for PTSD: A Survey

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Abstract

Virtual reality (VR) technology is emerging as a transformative tool in the treatment of post-traumatic stress disorder (PTSD), offering immersive and controlled environments that facilitate the safe confrontation and processing of traumatic experiences. This survey explores the integration of VR in mental health therapy, highlighting its potential to enhance therapeutic outcomes through multimodal and sensory feedback, which enriches user engagement and emotional processing. Recent advancements in VR hardware and software, alongside the incorporation of artificial intelligence (AI) and machine learning (ML), have significantly improved the precision, accessibility, and effectiveness of VR experiences. These technologies enable personalized and adaptive interventions that align with real-time emotional and physiological data, advancing emotion detection and regulation. Despite these promising developments, challenges such as hardware limitations, cybersickness, and ethical concerns regarding data privacy and user consent must be addressed to ensure successful implementation. Future research opportunities include expanding VR applications beyond PTSD to a broader spectrum of mental health conditions, integrating advanced technologies for enhanced personalization, and innovating VR content and environments. Additionally, rigorous research methodologies and data collection techniques will be crucial for advancing the field and ensuring the development of effective and personalized VR interventions. As research progresses, VR technology holds the potential to revolutionize PTSD treatment and mental health therapy, offering innovative solutions that improve therapeutic outcomes and patient well-being.

1 Introduction

1.1 Overview of Virtual Reality in Psychiatry

Virtual reality (VR) has emerged as a transformative tool in psychiatry, providing innovative therapeutic opportunities through immersive environments that enable patients to confront anxiety-inducing stimuli safely. This approach enhances therapeutic outcomes by facilitating reduced anxiety and increased patient engagement during therapy sessions [1, 2]. Beyond exposure therapy, VR's applications extend to emotion regulation and strengthening therapeutic alliances, with customizable environments optimizing intervention efficacy [3]. The integration of stress detection models, utilizing voice analysis for real-time feedback, aligns therapeutic processes with physiological stress indicators, further enhancing efficacy [4].

Recent advancements position VR as a dynamic mechanism for emotion elicitation, addressing literature gaps regarding its effectiveness compared to passive methods [5]. The incorporation of multimodal technologies enhances user experience by improving realism, attention, and performance [6]. The categorization of extended reality (XR) technologies, which includes VR, augmented reality (AR), and mixed reality (MR), underscores their unique contributions to immersive experiences [7].

VR's role in emotion recognition is being explored through EEG signal analysis in immersive environments, highlighting the need for 3D datasets to improve accuracy in emotion elicitation [8].

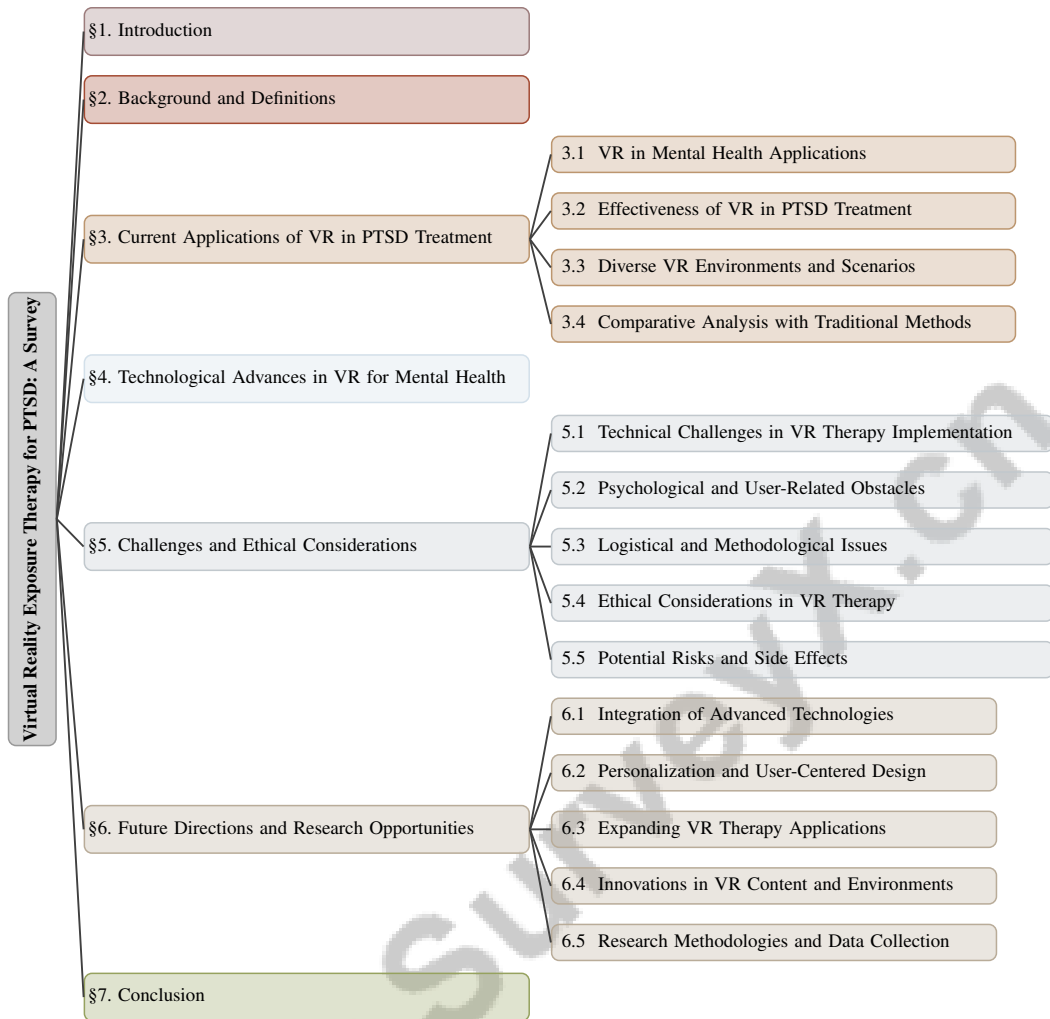


Figure 1: chapter structure

Strategies to minimize cybersickness, a common VR issue, are under development to enhance user comfort [9].

In conflict resolution, VR offers transformative insights by enabling individuals to embody their partner's perspective, fostering empathy and understanding [10]. The feasibility of VR in creating emotionally evocative environments is under investigation, with implications for emotion regulation training [11]. The Component Process Model (CPM) framework is introduced to explore emotions within interactive VR games, emphasizing a data-driven approach to capturing emotional experiences [12].

As research progresses, VR is set to play an increasingly pivotal role in psychiatry, expanding therapeutic possibilities and enhancing patient experiences. The integration of eHealth technologies and user-centered design is crucial for implementing virtual therapeutic communities effectively [13]. Exploring VR through instrumental realism further emphasizes its capacity to expand human perception and cognition [14].

1.2 Significance of VR in Mental Health Treatment

Virtual reality (VR) signifies a major advancement in treating mental health disorders, utilizing its immersive capabilities to enhance therapeutic practices. Its ability to simulate realistic, interactive environments provides a unique platform for addressing complex emotional and psychological issues, particularly in post-traumatic stress disorder (PTSD) treatment, where VR exposure therapy (VRET)

enables safe confrontation of traumatic memories, promoting recovery and reducing anxiety [2]. Recent studies highlight metaphorical interactions within VR, allowing patients to engage with negative thoughts innovatively, thereby improving therapeutic outcomes [15].

The integration of VR in mental health treatment is further supported by its potential to enhance communication skills and empathy, especially in conflict resolution scenarios. By allowing individuals to experience different perspectives, VR addresses the emotional complexities in close relationships [10]. Additionally, VR's role in emotion regulation training is crucial for improving mental health outcomes among youth, positively impacting educational and socio-emotional development [11].

VR's transformative potential is amplified when combined with eHealth technologies, which empower patients, reduce isolation, and offer cost-effective treatment solutions [13]. The incorporation of AI and VR in medical applications enhances these benefits, providing new avenues for visualization, data processing, and intervention [16]. The exploration of emotional experiences within VR environments, including the Metaverse, underscores VR's importance in evoking and measuring emotional responses, enriching therapeutic practices [17].

As VR technology evolves, its application in mental health treatment is poised to expand, offering innovative solutions for various psychiatric disorders. Recent surveys emphasize VR's transformative potential in enhancing assessment and treatment across conditions [18]. Ongoing research underscores VR's critical role in advancing mental health therapy, particularly for disorders like PTSD, where traditional methods may face limitations [14].

1.3 Scope and Objectives

This survey comprehensively explores the integration and application of virtual reality (VR) technologies in treating post-traumatic stress disorder (PTSD), emphasizing VR's transformative potential in mental health therapy. The scope includes immersive VR technologies for assessing, theorizing, and treating adult mental health disorders, particularly PTSD [1]. Additionally, the survey considers VR's broader applications in various psychiatric disorders, including anxiety disorders, obsessive-compulsive disorder (OCD), substance use disorders, eating disorders, psychosis, autism spectrum disorder, and attention deficit hyperactivity disorder (ADHD) [19].

Beyond therapeutic effectiveness, the survey investigates the design and utility of virtual environments for remote counseling, highlighting VR's role in enhancing outcomes through tailored experiences [3]. It also addresses challenges and opportunities associated with conducting VR studies remotely, particularly regarding home VR setups and user willingness to engage [20].

The main objectives are to evaluate current VR applications and effectiveness in PTSD treatment, examine technological advancements facilitating these applications, and identify challenges and ethical considerations in VR therapy. Furthermore, the survey explores potential future directions for VR therapy, considering the integration of advanced technologies such as artificial intelligence (AI), augmented reality (AR), and the Metaverse, which are set to further transform therapeutic practices [21]. This comprehensive review aims to contribute to the growing literature on VR as a therapeutic tool in psychiatry, reinforcing its significance in enhancing mental health treatment [22].

1.4 Structure of the Survey

This survey is meticulously structured to provide a comprehensive exploration of the integration of virtual reality (VR) in treating post-traumatic stress disorder (PTSD) and its broader implications in mental health therapy. The paper is organized into several key sections, each addressing different aspects of VR therapy, supported by a thorough review of existing literature and recent advancements in the field.

The survey begins with an **Introduction**, discussing the significance of VR in mental health treatment, particularly for PTSD, and outlining the scope and objectives of the paper.

Following the introduction, the **Background and Definitions** section delves into fundamental concepts related to VR, PTSD, and Virtual Reality Exposure Therapy (VRET), tracing the evolution of VR technology and its application in mental health.

The next section, **Current Applications of VR in PTSD Treatment**, reviews existing studies and applications of VR in treating PTSD, examining diverse VR environments and scenarios employed in exposure therapy and assessing their effectiveness and limitations compared to traditional methods.

In **Technological Advances in VR for Mental Health**, the survey explores recent technological innovations that enhance VR's application in therapy. Advancements in hardware and software, along with the integration of artificial intelligence (AI) and machine learning, are improving treatment efficacy across various fields, particularly in medicine. This includes AI-enhanced VR applications that improve medical diagnosis and intervention through immersive experiences, as well as multimodal and sensory technologies facilitating emotional expression in communication tools like speech-to-text interfaces [23, 21, 1, 16, 18].

The **Challenges and Ethical Considerations** section identifies the technical, psychological, logistical, and ethical challenges associated with implementing VR therapy for PTSD, addressing potential risks and side effects that necessitate careful consideration in deploying VR interventions.

The penultimate section, **Future Directions and Research Opportunities**, discusses potential future developments in VR therapy for PTSD, highlighting areas for further research and innovation, considering the integration of advanced technologies and the expansion of VR therapy applications beyond PTSD.

In the **Conclusion**, the survey summarizes key findings and insights, emphasizing VR's transformative potential in enhancing PTSD treatment and improving mental health therapy overall. It highlights how VR applications, such as retrospective embodied perspective-taking and immersive exposure therapies, have demonstrated effectiveness in fostering emotional regulation, improving communication skills, and facilitating conflict resolution in therapeutic settings. These advancements suggest that VR could revolutionize traditional therapeutic approaches, making mental health interventions more engaging and effective for diverse populations [1, 10, 22, 6, 11]. Through this structured approach, the survey aims to contribute to the ongoing discourse on VR as a pivotal tool in psychiatric treatment. The following sections are organized as shown in Figure 1.

2 Background and Definitions

2.1 Key Concepts and Definitions

Virtual Reality (VR) is a sophisticated medium that immerses users in interactive 3D environments, crucial for therapeutic applications by enabling controlled exposure to anxiety-inducing stimuli, thus facilitating treatment processes [2]. The integration of Artificial Intelligence (AI) into VR enhances diagnostic and treatment methodologies [16], although accurately measuring stress levels and their effects on performance within VR remains challenging [24].

Post-Traumatic Stress Disorder (PTSD) is a complex mental health condition stemming from traumatic events, characterized by symptoms such as intrusive memories and heightened arousal. VR's application in PTSD treatment is part of broader investigations into its efficacy for various psychological disorders, including anxiety and phobias [2]. Implementing VR in therapy requires understanding emotional dynamics to prevent emotional hijacking, where overwhelming emotions disrupt cognitive processes [17].

Virtual Reality Exposure Therapy (VRET) recreates real-world scenarios, allowing patients to confront traumatic experiences in a safe environment. This method is effective in PTSD treatment by enabling safe re-exposure to trauma, reducing anxiety, and fostering recovery [2]. The design of virtual environments in VRET significantly impacts therapeutic alliances and the efficacy of remote counseling sessions [25].

Additionally, VR in neuroscience research offers platforms for exploring human cognition and behavior [26]. VR's potential to create mystical-type experiences (MTEs) without psychedelics underscores its capacity to elicit profound emotional and cognitive responses [27]. Time perception within VR environments critically shapes user experiences and interactions [28].

2.2 Evolution of VR Technology

The evolution of VR technology has significantly influenced its application in mental health, particularly for therapeutic purposes. Early VR systems were limited by basic hardware and software, restricting their capacity to create immersive therapeutic environments. The transition from three degrees of freedom (3-DOF) to six degrees of freedom (6-DOF) in head-mounted displays (HMDs) marks a crucial advancement, enhancing interactivity and realism, thereby improving user engagement and therapeutic outcomes [29].

VR technology's shift from laboratory settings to consumer markets increased accessibility and its application in mental health [14]. Despite advancements, challenges like cybersickness persist, affecting user experiences. The Cybersickness Questionnaire for Virtual Reality (CSQ-VR) provides a more reliable assessment tool compared to earlier measures like the Simulator Sickness Questionnaire (SSQ) and the Virtual Reality Sickness Questionnaire (VRSQ) [30]. Addressing cybersickness is essential for ensuring user comfort and efficacy in VR mental health applications.

The classification and design of virtual environments have progressed, categorizing VR media into visual or audio-visual stimuli, games and tasks, 360-degree media, and mixed reality, all contributing to emotion induction [5]. Research into multimodality has further enhanced user immersion, improving attention and performance [6].

Software advancements have enriched VR capabilities, particularly through physiological data collection, such as heart rate and heart rate variability (HRV), enabling dynamic stress analysis and insights into user experiences and emotional responses [24]. Applications like Magic Xroom systematically elicit and recognize emotions by adjusting task difficulty to user skill levels, addressing unimodal data limitations [31].

Despite these advancements, challenges remain in integrating AI-VR technologies within healthcare frameworks. The lack of high-quality, diverse datasets for AI training, alongside ethical concerns regarding patient privacy and data security, poses significant barriers [16]. The technical complexities of VR systems and the need for interdisciplinary collaboration complicate synchronization and analysis of heterogeneous data collected during VR experiments [26].

The historical progression of VR technology is marked by ongoing advancements towards more immersive, interactive, and user-friendly systems, expanding VR's potential applications in mental health and providing innovative tools for enhancing therapeutic outcomes. As VR technology evolves, it promises increasingly sophisticated solutions for mental health treatment, particularly in integrating emotional expressions within VR contexts [18].

2.3 Immersive Therapy and Mental Health Technology

Immersive therapy represents a groundbreaking approach in mental health technology, utilizing VR to create engaging therapeutic environments. This method harnesses VR's capability to simulate real-world scenarios, enhancing therapeutic outcomes, especially in trauma recovery. By allowing patients to confront and process traumatic events in a controlled setting, immersive therapy effectively reduces anxiety and fosters healing [17].

A vital aspect of immersive therapy is real-time stress monitoring, enriching the therapeutic process by providing immediate feedback on physiological responses. Recent advancements in stress assessment methodologies, particularly through electrocardiogram (ECG) data, have significantly improved stress detection accuracy compared to traditional models and existing deep learning approaches, highlighting the potential for real-time stress monitoring within VR applications and facilitating more personalized therapeutic interventions [32].

The efficacy of immersive therapy is further enhanced by incorporating somatic practices that encourage participants to focus on sensory experiences, deepening engagement with both virtual and physical environments, thus enriching the therapeutic experience [33]. Additionally, employing Human Perception-Optimized Planning (HPOP) in VR trajectory design minimizes sensory conflict, reducing VR sickness and enhancing the comfort and effectiveness of immersive therapy sessions [34].

To accurately capture emotional responses during immersive therapy, innovative rating methods have been developed, including continuous ratings during the VR experience and retrospective

assessments afterward. These approaches enable comprehensive analysis of emotional reactions in relation to therapeutic objectives [35]. Furthermore, the Relative Subjective Time Change (RSTC) method provides insights into the interplay between time perception and user experience, crucial for understanding interactions within immersive environments [28].

Immersive therapy, particularly through VR, signifies a significant advancement in mental health technology, especially for trauma recovery, effectively facilitating exposure therapy for PTSD and various anxiety disorders by providing controlled environments for patients to confront and process their fears [1, 22]. By leveraging VR's immersive capabilities alongside sophisticated monitoring and assessment tools, this approach offers a promising pathway for enhancing therapeutic outcomes and supporting individuals on their journey toward mental health recovery.

3 Current Applications of VR in PTSD Treatment

3.1 VR in Mental Health Applications

Virtual reality (VR) is pivotal in mental health, especially for treating post-traumatic stress disorder (PTSD), by creating controlled environments where patients can confront and process trauma, thereby promoting emotional healing and reducing anxiety [2]. Multimodal technologies enhance this therapeutic potential by providing comprehensive sensory feedback, enriching user experience and outcomes [24].

In therapeutic settings, VR facilitates various interventions, such as Virtual Reality for Emotion Regulation Training (VREMRT), which immerses youth in emotionally charged scenarios to practice cognitive reappraisal [11]. Applications like Mind Mansion help users manage negative thoughts through immersive experiences, offering innovative therapeutic avenues [15]. Interactive VR games, leveraging the Component Process Model (CPM), explore emotional differentiation, serving as platforms for understanding complex emotional responses and enhancing therapeutic strategies [12, 17].

Cybersickness remains a challenge, potentially impairing user performance and comfort. The Cybersickness Questionnaire for Virtual Reality (CSQ-VR) aids in detecting and measuring symptoms, optimizing VR environments for user well-being [14]. Addressing these challenges is crucial for maintaining VR's therapeutic integrity in mental health.

VR also enhances communication for individuals with disabilities, such as Deaf and Hard of Hearing (DHH) individuals, through technologies like Live Transcribe and emotive captioning, improving accessibility in therapeutic settings [18]. In relational emotion processing therapy (REPT), VR allows individuals to revisit past interactions from different perspectives, promoting empathy and understanding [27]. Diverse measurement techniques enhance understanding of user engagement and experiences in mixed reality (MR), contributing to a better grasp of immersive technologies [25]. VR's application in PTSD treatment underscores its transformative potential in creating immersive therapeutic environments supporting emotional regulation and recovery [16].

3.2 Effectiveness of VR in PTSD Treatment

VR is a promising tool for PTSD treatment, offering unique advantages over traditional methods. Its immersive nature facilitates controlled environments for patients to engage with and process traumatic experiences, enhancing exposure therapy's effectiveness [15]. This active engagement contrasts with traditional methods, as interactive VR games evoke a broader range of emotions, improving emotional awareness and coping strategies [12].

The effectiveness of VR in treating PTSD and anxiety disorders is well-documented, with significant improvements in emotional regulation and therapeutic outcomes [13]. Advanced visualization and data processing techniques further enhance VR interventions' efficacy [16]. Additionally, facial emotion recognition within VR gaming contexts, using CNN models, has effectively categorized emotions, enriching the therapeutic experience [36].

Despite advancements, VR's application in PTSD treatment faces limitations, including high costs and the need for standardization [2]. Concerns regarding VR sickness persist, although recent developments in human perception-optimized planning have reduced symptoms, enhancing user comfort and overall effectiveness [34]. Empirical studies on VR's impact on physiological responses, such as

heart rate and heart rate variability (HRV) under stress, underscore the importance of comprehensive emotional feedback mechanisms within VR therapy [24]. However, the long-term effectiveness of VR interventions, particularly in chronic pain management, requires further investigation [2].

3.3 Diverse VR Environments and Scenarios

VR environments are crucial for effective exposure therapy in PTSD treatment, recreating real-world settings or generating metaphorical scenarios for patients to confront traumatic memories in a controlled manner. The diversity of VR environments is vital for customizing therapeutic experiences to individual needs, thereby enhancing treatment efficacy [2].

VR applications in PTSD treatment involve creating immersive environments that simulate contexts or events associated with trauma, enabling gradual re-exposure to traumatic stimuli for desensitization and emotional processing [15]. For example, VR scenarios can realistically reproduce combat situations for veterans or urban settings for individuals traumatized in city environments [12]. Metaphorical environments allow patients to engage with trauma indirectly, fostering emotional resilience and cognitive reappraisal—essential components of recovery [11].

Interactive elements within VR environments enhance therapeutic outcomes by promoting active participation. Interactive VR games evoke a range of emotional responses, providing platforms for practicing emotional regulation and coping strategies [27, 12]. Multimodal and sensory technologies in VR environments enrich user experience with comprehensive sensory feedback, crucial for maintaining immersion and enhancing the therapeutic process [24, 6].

3.4 Comparative Analysis with Traditional Methods

VR therapy offers distinct advantages over traditional PTSD treatments, such as cognitive-behavioral therapy (CBT) and prolonged exposure therapy, which rely on verbal recounting of traumatic events and cognitive restructuring. While effective for many, these methods often require significant patient engagement and may not fully capture trauma's sensory and emotional dimensions [2].

In contrast, VR therapy provides an immersive platform for controlled re-exposure to traumatic stimuli, evoking comprehensive emotional responses that facilitate deeper processing and desensitization [15]. VR's ability to simulate realistic scenarios enables patients to confront and process trauma in engaging ways, potentially leading to rapid and sustained improvements in PTSD symptoms [12].

VR's integration of multimodal and sensory feedback enhances the therapeutic process, offering a holistic treatment experience. Visual, auditory, and haptic elements in VR environments maintain patient immersion and engagement, crucial for successful exposure therapy [24]. This sensory-rich approach contrasts with traditional therapies' primarily verbal focus, providing an alternative for patients who may struggle with verbal expression or cognitive engagement [6].

Despite advantages, VR therapy faces challenges, including high equipment costs and the need for specialized therapist training, limiting accessibility [2]. Issues such as cybersickness and individualized scenario design need addressing to optimize therapeutic outcomes [14]. However, advancements in human perception-optimized planning and reliable measures for cybersickness symptoms have made significant strides in addressing these concerns, enhancing VR therapy's feasibility and comfort [34].

4 Technological Advances in VR for Mental Health

The technological advancements in virtual reality (VR) for mental health therapy underscore a transformative trajectory, enhancing therapeutic efficacy through innovations in tracking systems, artificial intelligence (AI), and other emerging technologies. Transitioning from 3-DOF to 6-DOF tracking systems significantly improves user locomotion and immersion. As illustrated in ??, these advancements can be categorized into three primary areas: innovations in hardware and software, the role of AI and machine learning in VR therapy, and the integration of multimodal and sensory technologies. Each area is further detailed with specific advancements and applications that enhance therapeutic efficacy and user experience. Table 1 provides a comprehensive overview of the technological advancements in VR for mental health, detailing the innovations in hardware and software, AI and machine learning applications, and multimodal and sensory integration that enhance therapeutic

Category	Feature	Method
Innovations in Hardware and Software	Symbolic and Experiential Processing Temporal and Real-Time Analysis	MM[15], ISN[27] CREM[35], TPM-Net[28]
AI and Machine Learning in VR Therapy	User Experience Enhancement Feature Detection	CPS[9] FER-VR[36]
Multimodal and Sensory Integration	Sensory Feedback	HPOP[34], VRGWAP[24]

Table 1: The table summarizes key technological advancements in virtual reality (VR) for mental health therapy, categorized into innovations in hardware and software, the role of AI and machine learning in VR therapy, and multimodal and sensory integration. Each category highlights specific features and methodologies that contribute to enhancing therapeutic efficacy and user experience in VR environments.

outcomes. Additionally, Table 3 presents a detailed comparison of the technological advancements in VR for mental health, showcasing innovations in hardware and software, the role of AI and machine learning, and multimodal and sensory integration to enhance therapeutic efficacy and user experience. The integration of AI and emerging technologies streamlines processes and broadens VR applications across fields, contributing to more immersive therapeutic environments [29, 21, 20, 14].

4.1 Innovations in Hardware and Software

Method Name	Technological Advancements	Therapeutic Applications	User Engagement
TPM-Net[28]	Cnn And Transformer	Therapy Potential Applications	Deeper Emotional Connections
CREM[35]	VR Headsets	Emotion Tracking	360° VR Videos
MM[15]	-	Mental Self-care	Metaphorical Representations
ISN[27]	Immersive Technologies	Emotion Recognition	Multi-person VR

Table 2: Overview of technological advancements, therapeutic applications, and user engagement in recent VR-based mental health interventions. The table highlights the innovative methods employed, including TPM-Net, CREM, MM, and ISN, showcasing their unique contributions to enhancing emotional connections and therapeutic outcomes.

Recent advancements in VR hardware and software have greatly enhanced user experiences and therapeutic outcomes in mental health applications. Table 2 provides a comprehensive overview of the recent technological advancements and their applications in virtual reality (VR) for mental health, illustrating the diverse methodologies and user engagement strategies employed to enhance therapeutic effectiveness. Innovations in head-mounted displays (HMDs), motion tracking systems, and multi-modal biosensing devices collectively enhance the precision and fluidity of VR experiences, fostering immersive therapeutic environments [26]. On the software side, the Time Perception Modeling Network (TPM-Net) leverages CNN and Transformer architectures to model time perception, capturing fine-grained temporal dependencies vital for emotion recognition and therapeutic interventions [28]. Real-time emotion tracking through continuous ratings offers a more reliable assessment of emotional states compared to traditional retrospective methods [35].

Applications like Mind Mansion employ physical engagement and metaphorical representations to enhance user experience and therapeutic outcomes, fostering deeper emotional connections with the virtual environment [15]. Additionally, simulating psychedelic effects in multi-person VR experiences provides shared insights and connectedness without the associated risks [27]. These innovations emphasize VR’s transformative potential in mental health therapy, offering methodologies for improved user engagement and therapeutic outcomes. As VR technology evolves, it is poised to offer sophisticated interventions for psychiatric disorders, enhancing therapies for anxiety disorders by enabling realistic interactions with feared stimuli [1, 22].

4.2 AI and Machine Learning in VR Therapy

Artificial intelligence (AI) and machine learning (ML) are pivotal in advancing VR therapy, particularly in emotion detection and regulation. AI facilitates sophisticated algorithms that recognize emotional cues, enhancing the therapeutic process. Convolutional Neural Networks (CNNs) improve emotion detection accuracy in VR environments, even with occluded facial features [36]. ML classifiers predict user discomfort during VR gameplay, crucial for minimizing cybersickness and enhancing user comfort [9]. These technologies analyze diverse data streams from VR systems and

sensors, synthesizing complex datasets to enhance user interaction understanding [26]. As AI and ML evolve, their role in VR therapy is expected to expand, offering new avenues for enhancing emotional regulation and therapeutic efficacy, particularly in disorders like PTSD [1, 22].

4.3 Multimodal and Sensory Integration

The integration of multimodal and sensory technologies in VR therapy significantly enhances treatment efficacy for mental health disorders, including PTSD. By incorporating multiple sensory modalities, VR therapy creates immersive environments that facilitate deeper emotional processing [6]. Multimodal integration uses visual, auditory, and haptic feedback to create comprehensive sensory experiences, enhancing realism and user engagement. Haptic feedback provides tactile sensations that mimic real-world interactions, increasing user immersion [24].

Advancements in multimodal VR systems focus on optimizing sensory input synchronization to minimize sensory conflict and enhance user comfort. Human Perception-Optimized Planning (HPOP) aligns visual and vestibular cues to reduce VR sickness [34]. Integrating physiological data collection within VR environments allows real-time monitoring of user responses, tailoring interventions to individual needs [24]. This integration not only enhances the immersive quality of the therapeutic environment but also supports the development of personalized treatment strategies. As VR technology advances, immersive exposure therapies and emotional expression recognition will significantly enhance VR therapy's effectiveness, expanding possibilities for emotional healing and recovery in psychiatric disorders [18, 1, 10, 22].

Feature	Innovations in Hardware and Software	AI and Machine Learning in VR Therapy	Multimodal and Sensory Integration
Technological Focus	Hmds And Tpm-Net	Cnns And ML	Haptic Feedback
Therapeutic Application	Emotion Recognition	Emotion Detection	Ptsd Treatment
User Experience Enhancement	Immersive Environments	Minimize Cybersickness	Enhanced Realism

Table 3: This table provides a comparative analysis of technological advancements in virtual reality (VR) for mental health therapy, focusing on three key areas: innovations in hardware and software, applications of artificial intelligence (AI) and machine learning, and the integration of multimodal and sensory technologies. It highlights the technological focus, therapeutic applications, and user experience enhancements associated with each area, demonstrating their contributions to improving therapeutic outcomes in VR-based mental health interventions.

5 Challenges and Ethical Considerations

Virtual reality (VR) therapy for post-traumatic stress disorder (PTSD) presents numerous challenges and ethical considerations crucial for its effective deployment. While VR studies predominantly focus on anxiety disorders, the need for immersive environments that enhance therapeutic engagement is evident. Recent pilot studies highlight the necessity of customizing VR settings to cater to specific therapeutic needs, establishing clear boundaries to strengthen therapeutic relationships and improve outcomes [1, 3]. These challenges span technical, psychological, logistical, and ethical dimensions, impacting VR's efficacy and acceptance as a therapeutic modality.

Technical challenges significantly influence VR therapy's therapeutic experience. The varied methodologies in VR studies complicate the establishment of standardized metrics for capturing user experiences [25]. Consumer-grade VR hardware limitations can hinder effective multimodal experiences, leading to overwhelming sensory feedback that detracts from therapy [6]. Furthermore, reliance on specific datasets for emotion recognition may not generalize across different VR content or demographics, limiting intervention applicability [8].

Transitioning from controlled laboratory settings to remote environments introduces variability in user experiences, necessitating frameworks to standardize approaches [20]. This variability underscores the need for real-time quality assessment and subjective testing methodologies to reliably evaluate VR therapy's effectiveness [23]. Cybersickness remains a concern, with assessments relying on self-reported discomfort, introducing subjectivity [9]. Developing automatic recommendation strategies to mitigate cybersickness symptoms is crucial for enhancing comfort and engagement. Additionally, VR technology's high costs and variability in hardware and software requirements pose barriers to widespread adoption [2].

Implementing relational emotion processing therapy (REPT) within VR requires advanced technologies that accurately reflect past interactions, emphasizing the need for sophisticated VR systems [10]. The stigma surrounding mental health treatment and the costs of traditional therapeutic communities further complicate patient engagement, particularly for borderline personality disorder (BPD) [13]. Addressing these challenges through standardized methodologies, comprehensive assessment tools, and cost-effective solutions is essential for successfully implementing VR therapy for PTSD, which has shown promise as an effective treatment for anxiety-related conditions [19, 2, 1, 22, 3].

5.1 Technical Challenges in VR Therapy Implementation

Implementing VR therapy for PTSD involves several technical challenges that must be addressed to enhance therapeutic efficacy. The diversity of methodologies in VR studies complicates establishing standardized metrics for accurately capturing user experiences [25]. This lack of consistency hinders the generalization of findings across different studies and applications.

Consumer-grade VR hardware limitations impede effective multimodal experiences, often leading to suboptimal sensory feedback integration that overwhelms users and detracts from therapy [6]. The reliance on specific datasets for emotion recognition may not translate well to various VR content or diverse demographic groups, limiting intervention generalizability [8].

Transitioning from controlled laboratory settings to remote environments introduces variability in user experiences, necessitating frameworks to categorize and standardize approaches [20]. This variability underscores the need for real-time quality assessment and subjective testing methodologies to reliably evaluate VR therapy's effectiveness [23].

Cybersickness remains prevalent, with assessments often relying on self-reported discomfort levels, introducing subjectivity [9]. Developing automatic recommendation strategies to mitigate cybersickness is crucial for enhancing user comfort and engagement. Additionally, VR technology's high costs and variability in hardware and software requirements pose further barriers to widespread adoption [2].

Implementing relational emotion processing therapy (REPT) within VR requires sophisticated technologies capable of accurately reflecting past interactions, emphasizing the need for advanced VR systems [10]. The stigma surrounding mental health treatment and the high costs of traditional therapeutic communities complicate patient engagement, particularly for individuals with BPD [13].

Addressing these technical challenges requires developing standardized methodologies, comprehensive assessment tools, and cost-effective solutions for successfully implementing VR therapy for PTSD. Overcoming current limitations in VR therapy can make it a more effective and accessible treatment modality for PTSD and other mental health disorders, given its proven efficacy in anxiety-related conditions [19, 2, 1, 22, 3].

5.2 Psychological and User-Related Obstacles

VR therapy for PTSD faces psychological and user-related challenges that influence its effectiveness. Variability in user acceptance and engagement, particularly when therapeutic content does not resonate with users, is a significant issue. Predefined negative thoughts in therapeutic VR environments may not align with all users' personal experiences, potentially limiting emotional impact and engagement [15].

Regulating emotions within VR environments poses challenges, especially for adolescents susceptible to emotional manipulation. VR's immersive nature can amplify emotional responses, complicating users' ability to manage emotions effectively, crucial for therapeutic success [17]. Accurately detecting and responding to nuanced emotional cues is essential for enhancing the therapeutic process.

User engagement is further challenged by emotional hijacking, where intense emotional experiences in VR can overwhelm cognitive functions, hindering therapy. This is particularly concerning for younger users lacking emotional regulation skills to navigate complex scenarios in VR [17]. Additionally, reliance on passive methods in studies may not capture the full spectrum of emotional experiences, limiting VR's therapeutic potential.

Addressing these obstacles is critical for improving VR therapy's efficacy and acceptance for PTSD. By creating personalized and adaptive VR environments catering to users' unique emotional needs, VR therapy can enhance its effectiveness, increasing acceptance and application in clinical settings. This approach leverages immersive technology to simulate real-life scenarios for exposure therapy and emphasizes customization in therapeutic settings, improving engagement and therapeutic relationships. Such advancements could broaden VR therapy's scope, making it viable for a wider range of mental health conditions [19, 2, 1, 22, 3].

5.3 Logistical and Methodological Issues

Deploying VR therapy for PTSD involves logistical and methodological challenges hindering its adoption and effectiveness. High costs and technical complexity associated with VR systems limit accessibility for patients and healthcare providers. The need for specialized equipment, like high-quality head-mounted displays and motion tracking systems, poses significant barriers, especially in underfunded healthcare settings [2].

Methodologically, the absence of standardized protocols for VR therapy presents challenges in ensuring consistent and reliable outcomes. The diversity of VR applications and variability in user experiences necessitate comprehensive frameworks to guide VR therapy design and implementation across settings [25]. Establishing standardized metrics for assessing engagement and efficacy is critical for evaluating VR interventions' success.

Integrating VR therapy into existing healthcare systems often requires significant adjustments in clinical workflows and training for healthcare professionals. Cross-disciplinary collaboration among technologists, clinicians, and researchers is essential to address integration challenges and develop effective VR applications [26].

Furthermore, transitioning from controlled laboratory settings to real-world applications introduces variability in user experiences, emphasizing the need for robust methodologies accommodating diverse user needs and preferences. Developing adaptive VR environments tailored to individual users is crucial for enhancing VR therapy's personalization and effectiveness [20].

Addressing logistical and methodological challenges is vital for successfully deploying VR therapy for PTSD. By tackling current VR therapy limitations, such as immersive technology needs and VR environment validation, this innovative treatment modality can become more accessible and effective for managing various mental health disorders, particularly anxiety-related conditions. Recent studies highlight VR's efficacy in exposure therapies, evoking realistic responses to feared stimuli and enhancing therapeutic outcomes for specific phobias, social anxiety, and PTSD [1, 22].

5.4 Ethical Considerations in VR Therapy

Integrating VR therapy into mental health treatment, particularly for PTSD, requires careful consideration of ethical concerns. A primary issue is protecting patient data and privacy, a significant obstacle in adopting AI and VR technologies in therapeutic settings [16]. Secure storage and transmission of patient information are crucial for maintaining trust and legal compliance.

Data privacy risks and cybersecurity vulnerabilities in VR environments present additional challenges. Immersive technologies can expose users to unauthorized data collection and manipulation, necessitating robust cybersecurity measures to protect sensitive information [7]. Addressing these risks is essential for safeguarding user privacy and ensuring VR therapy's ethical deployment.

Moreover, VR therapy design and implementation must consider ethical implications of user consent and potential psychological manipulation. Ensuring participants are fully informed about VR experiences and data collection is vital for obtaining meaningful consent [10]. This is particularly important in conflict resolution scenarios, where privacy concerns related to recorded discussions must be addressed.

The potential for addiction and dissociation in immersive environments raises further ethical concerns. Prolonged VR exposure can lead to adverse psychological effects, necessitating guidelines to mitigate risks and promote healthy engagement [7]. Additionally, the influence of zeitgebers on time perception in VR suggests therapeutic environment design should consider ethical implications of altering users' temporal experiences [28].

Finally, ethical considerations surrounding empathy in AI and user data privacy are critical for VR technologies' future development. As VR therapy evolves, prioritizing user-centered design that enhances meaningful interactions while addressing ethical concerns related to privacy and data security is imperative [14]. Addressing these ethical challenges allows VR therapy to be implemented in a manner that respects user rights and promotes positive therapeutic outcomes.

5.5 Potential Risks and Side Effects

VR therapy for PTSD presents several potential risks and side effects that must be managed to ensure patient safety and therapeutic efficacy. VR sickness, characterized by dizziness, nausea, and disorientation, can significantly impact user comfort and therapy effectiveness. Addressing VR sickness is crucial, as it can detract from the immersive experience central to VR therapy's success [34].

Efforts to mitigate VR sickness focus on optimizing VR environment design to align with human perception, reducing sensory conflict and enhancing comfort. This involves careful planning of VR trajectories and integrating multimodal sensory feedback to create a stable experience [34]. Calibrating VR systems to minimize adverse effects is essential for maintaining high user presence and engagement, critical for achieving therapeutic outcomes in PTSD treatment.

In addition to VR sickness, concerns regarding immersive environments' psychological effects, particularly related to emotional regulation and anxiety disorders, necessitate careful consideration of VR's psychological implications. Research indicates that while VR can effectively treat anxiety and other psychiatric disorders through exposure therapies, it may also elicit strong emotional reactions impacting mental health, necessitating careful tailoring of content to therapeutic needs [9, 1, 20, 22, 11]. Intense emotional experiences in VR therapy may lead to overwhelm or distress, underscoring the importance of personalized scenarios aligning with users' emotional capacities and goals.

Prolonged exposure to immersive VR environments poses a risk of dissociation or detachment from reality, a concern highlighted in literature on VR's safety and effectiveness in cognitive neuroscience and neuropsychology. While VR technologies, like the VR Everyday Assessment Lab (VR-EAL), offer enhanced ecological validity for assessing cognitive functions, they also present methodological challenges needing addressing to mitigate psychological risks. Extensive VR use in treating anxiety disorders underscores the need for careful monitoring of participants' mental states during and after immersive experiences, as VR's immersive nature can alter reality perceptions [20, 1, 37]. This highlights the necessity of guidelines and monitoring to ensure VR therapy sessions are conducted safely and users receive adequate support throughout the therapeutic process.

By addressing these risks and side effects, VR therapy for PTSD can be implemented more effectively, providing a safe and supportive environment for individuals to confront and process traumatic experiences. As VR technology progresses, ongoing research and development efforts must focus on optimizing therapeutic protocols and improving VR interventions' safety and effectiveness for mental health treatment. Recent literature underscores VR's significant potential in addressing various psychiatric disorders, particularly anxiety-related conditions, through immersive exposure therapies eliciting realistic responses to feared stimuli. Such advancements emphasize the necessity of refining these interventions to maximize therapeutic benefits while ensuring patient safety and efficacy in clinical settings [1, 22].

6 Future Directions and Research Opportunities

The integration of advanced technologies, particularly virtual reality (VR), is poised to transform mental health treatment by redefining therapeutic practices. This section explores the potential of these technologies to enhance therapeutic outcomes and examines specific advancements in VR that promise to revolutionize the therapeutic landscape through immersive and tailored patient experiences.

6.1 Integration of Advanced Technologies

Combining advanced technologies with VR offers significant opportunities to enhance mental health treatment. Future research should focus on developing guidelines for VR applications, addressing

current limitations, and exploring trends in psychiatric care [2]. This includes designing diverse virtual environments for specific therapeutic needs, facilitating role-playing scenarios, and using standardized measures to evaluate VR's effectiveness in remote counseling [3].

Integrating additional sensory modalities into relational emotion processing therapy (REPT) can enhance immersive experiences and therapeutic outcomes [10]. Advancing Convolutional Neural Network (CNN) models for multi-angle emotion detection represents another avenue for VR therapy [36].

Developing virtual therapeutic community models for borderline personality disorder (BPD) should incorporate user-centered design principles and evaluate these interventions' effectiveness in real-world settings [13]. Further research should explore metrics for empathy assessment, cognitive empathy in chatbots, and emotional recognition in educational settings [18].

In AI integration, future studies should develop robust datasets, enhance AI-driven technology acceptance, and explore advanced AI techniques, such as natural language processing (NLP), in VR to improve patient interactions [16]. Investigating task-linked zeitgebers and advanced deep learning architectures to enhance model accuracy is also critical [28].

Improving VR technology's accessibility and affordability, exploring applications across medical conditions, and developing standardized protocols for VR therapy are essential for broader implementation and effectiveness [2]. By focusing on these areas, future research can significantly advance integrating advanced technologies with VR, enhancing therapeutic outcomes and expanding VR therapy's potential applications in mental health treatment.

6.2 Personalization and User-Centered Design

Personalized and user-centered design in VR therapy significantly enhances therapeutic efficacy by tailoring interventions to individual needs. Personalization involves creating customized virtual environments and scenarios aligned with users' therapeutic goals and emotional capacities, increasing engagement and relevance to improve treatment outcomes [15].

User-centered design principles emphasize involving users in the development process to ensure VR applications are intuitive and accessible, improving acceptance and engagement—critical factors for VR therapy success [13]. Incorporating user feedback allows developers to create VR environments that meet therapeutic needs, enhancing intervention effectiveness.

AI-driven emotion recognition and adaptive learning algorithms further enhance personalization in VR therapy. These technologies can dynamically adjust therapeutic content based on real-time user feedback and emotional responses, providing a more responsive experience, particularly beneficial for complex mental health disorders like PTSD.

Developing user-centered VR therapy applications should consider diverse user needs, including those with disabilities or differing technological proficiencies. Ensuring inclusivity and accessibility broadens the reach and impact of these interventions, making personalized mental health treatment available to a wider audience [18].

Integrating personalization and user-centered design in VR therapy can significantly enhance therapeutic outcomes by tailoring interventions to meet diverse populations' specific needs. Research indicates VR applications are particularly effective in treating anxiety disorders, where immersive environments facilitate exposure therapy and improve patient engagement. Pilot studies emphasize customizing virtual environments to align with various therapeutic approaches, fostering a stronger therapeutic alliance and optimizing remote counseling interventions' effectiveness [1, 3].

6.3 Expanding VR Therapy Applications

Expanding VR therapy applications beyond PTSD presents opportunities for addressing a broader spectrum of mental health conditions. Future research should prioritize developing personalized and theory-driven VR treatments that are accessible and cost-effective, enhancing therapeutic efficacy across diverse emotional contexts [15]. This is particularly relevant for youth, where improving VR technology accessibility can facilitate interventions supporting educational and socio-emotional development [11].

Exploring VR therapy applications in clinical populations should involve enhancing the embodiment illusion and developing an open-access library of immersive VR software, broadening VR interventions' scope for various psychological disorders [37]. Utilizing the Component Process Model (CPM) framework can expand VR therapy's application to other mental health conditions, providing deeper insights into emotional experiences across contexts [12].

Incorporating real-time stress detection into VR applications, particularly in scenarios like public speaking, can enhance training methods and improve user experiences [4]. This capability can be further developed by integrating multimodal approaches, including additional physiological signals, such as EEG, to enhance emotion recognition and provide comprehensive therapeutic interventions [8]. Future research should also explore additional physiological measures and larger participant groups to enhance findings' robustness and applicability [24].

VR therapy's potential to manipulate environmental factors, such as object size, to influence emotional responses offers another avenue for expanding its applications. This research can clarify the relationship between environmental cues and anxiety, informing more effective therapeutic environments' design [38]. Addressing cybersickness effects across age-diverse populations and its impact on cognitive functions can guide developing VR therapy applications tailored to broader demographics [30]. Future research should investigate additional criteria for user preferences and explore real-world applications, suggesting potential expansions of VR therapy beyond PTSD [34].

Furthermore, exploring emotional hijacking's implications in social contexts within the Metaverse can inform strategies to mitigate emotional manipulation and enhance emotional regulation [17]. Investigating the long-term impacts of Isness variations and comparing its effects to traditional psychedelic experiences can provide valuable insights into VR's therapeutic potential [27].

The expansion of VR therapy applications beyond PTSD to other mental health conditions holds promise for enhancing therapeutic outcomes and offering innovative solutions across a spectrum of psychological disorders. By leveraging advancements in VR technology and integrating comprehensive emotional and physiological assessments, VR therapy can become a versatile tool in mental health treatment [26].

6.4 Innovations in VR Content and Environments

Innovations in VR content and environments are pivotal for advancing therapeutic outcomes across a range of mental health disorders. Future research should prioritize refining VR applications to cater to broader psychiatric conditions, enhancing their applicability and effectiveness in diverse clinical settings [19]. This involves developing culturally relevant and sensitive VR environments, ensuring therapeutic interventions resonate with patients from various backgrounds.

Investigating VR therapy's long-term effects is essential for understanding its sustained impact on mental health outcomes. By examining these effects, researchers can identify VR's potential for lasting therapeutic benefits and inform more robust therapeutic protocols' development [19]. Incorporating dynamic and adaptive VR environments that respond to user feedback and emotional states can further enhance personalization and efficacy of therapeutic interventions.

Innovations in VR content also include integrating narrative-driven experiences that engage users meaningfully, fostering deeper emotional connections and facilitating therapeutic breakthroughs. By incorporating storytelling elements, VR therapy offers immersive experiences that facilitate exploring and processing complex emotions in a controlled environment. This approach enhances emotional expression through innovative technologies and addresses psychiatric disorders' specific needs, as evidenced by literature highlighting VR's effectiveness in exposure therapies for anxiety and stress management. Creating emotionally resonant scenarios enables patients to engage with their feelings more deeply, potentially leading to improved therapeutic outcomes [18, 22].

Advancing VR environments that replicate real-world situations or symbolize emotional challenges enhances therapeutic engagement and opens a wide array of applications across mental health, education, and healthcare by providing immersive experiences that foster emotional expression and facilitate effective remote counseling [18, 22, 3, 5]. These environments can be customized to address specific therapeutic goals, such as exposure therapy for anxiety disorders or skill-building exercises for emotional regulation.

Continuous innovation in VR content and environments holds significant promise for improving therapy outcomes. By focusing on cultural relevance, long-term efficacy, and personalized experiences, VR therapy can become a more effective and versatile tool in treating various psychiatric disorders, ultimately enhancing the quality of mental health care [19].

6.5 Research Methodologies and Data Collection

Benchmark	Size	Domain	Task Format	Metric
VRNQ[39]	120	Neuroscience	User Experience Assessment	VRNQ total score, VRISE score
CSQ-VR[30]	39	Psychology	Questionnaire	Total Score, Nausea Score

Table 4: Table illustrating benchmarks used in virtual reality research, detailing the benchmark names, their respective sizes, the domains they pertain to, task formats, and the metrics employed for evaluation. These benchmarks are integral for assessing user experiences and validating VR interventions, contributing to the development of standardized tools in VR research.

Studying VR therapy’s effectiveness necessitates robust research methodologies and comprehensive data collection techniques to ensure reliable and valid findings. Future research should prioritize strategies to mitigate ethical risks, enhance data security, and ensure inclusivity in adopting VR technologies, especially in human resource management and related fields [21]. Implementing rigorous ethical standards and data protection measures is essential to safeguard participant information and maintain trust in VR research practices.

To enhance research findings’ validity, studies should incorporate larger sample sizes and diverse VR hardware, allowing for generalization across different demographic groups and technological contexts. Validating tools like the Virtual Reality Neuroscience Questionnaire (VRNQ) is crucial for assessing user experiences and ensuring VR interventions’ applicability across varied settings [39]. Developing standardized assessment tools for mixed reality (MR) environments can facilitate evaluating user interactions and experiences, addressing technical challenges associated with measuring these experiences [25]. Table 4 provides a comprehensive overview of the benchmarks utilized in virtual reality research, highlighting their significance in enhancing the validity and applicability of VR interventions across various domains.

In emotion research, creating more diverse VR content is essential for eliciting a broader range of emotional responses. This can be achieved by improving emotion-sensing interfaces and establishing standardized datasets for emotion studies, enhancing the accuracy and consistency of emotion elicitation in VR environments [5]. Such advancements are critical for understanding VR therapy’s emotional impact and tailoring interventions to individual needs.

Remote VR studies present unique challenges regarding recruitment and data collection. Future research should explore innovative recruitment strategies and improve data collection methods to address demographic imbalances and ensure representative samples [20]. Leveraging technology to facilitate remote participation can expand VR studies’ reach and gather comprehensive data on VR interventions’ effectiveness.

Continuous advancement of research methodologies and data collection techniques is essential for exploring and validating VR therapy, particularly as recent studies highlight its effectiveness in treating psychiatric disorders and the potential for remote participation using consumer-owned head-mounted displays (HMDs), which can enhance study populations’ diversity and improve therapeutic interventions’ accessibility [20, 22]. Addressing these methodological challenges will contribute to developing more effective and personalized VR interventions, ultimately enhancing therapeutic outcomes in mental health treatment.

7 Conclusion

Virtual reality (VR) technology emerges as a revolutionary approach in the treatment of post-traumatic stress disorder (PTSD), offering immersive environments that facilitate the safe confrontation of traumatic experiences. This innovative approach not only aids in emotional healing but also enhances recovery by providing a controlled setting for processing trauma. The integration of multimodal

and sensory technologies within VR enriches the therapeutic experience, promoting deeper user engagement and emotional processing.

Recent advancements in VR technology, including improved hardware such as head-mounted displays and sophisticated motion tracking systems, have significantly enhanced the accessibility and effectiveness of VR applications in mental health. The incorporation of artificial intelligence (AI) and machine learning (ML) further augments VR therapy by enabling sophisticated emotion detection and regulation, allowing for interventions that adapt to real-time emotional and physiological data.

While the potential of VR therapy is promising, addressing technical challenges and ethical considerations remains crucial. Issues such as hardware limitations and cybersickness, along with concerns about data privacy and psychological manipulation, necessitate the development of robust guidelines and security measures. Future research should focus on integrating advanced technologies to further personalize and enhance VR therapy, expanding its application to a wider range of mental health conditions. Continued innovation in VR content and environments, supported by rigorous research methodologies, will be essential in advancing the field and ensuring the development of effective, personalized interventions.

References

- [1] Daniel Freeman, Sarah Reeve, Abi Robinson, Anke Ehlers, David Clark, Bernhard Spanlang, and Mel Slater. Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological medicine*, 47(14):2393–2400, 2017.
- [2] Lan Li, Fei Yu, Dongquan Shi, Jianping Shi, Zongjun Tian, Jiquan Yang, Xingsong Wang, and Qing Jiang. Application of virtual reality technology in clinical medicine. *American journal of translational research*, 9(9):3867, 2017.
- [3] Jiashuo Cao, Wujie Gao, Yun Suen Pai, Simon Hoermann, Chen Li, Nilufar Baghaei, and Mark Billingham. Explorations in designing virtual environments for remote counselling, 2024.
- [4] Arushi, Roberto Dillon, Ai Ni Teoh, and Denise Dillon. Voice analysis for stress detection and application in virtual reality to improve public speaking in real-time: A review, 2022.
- [5] Rukshani Somarathna, Tomasz Bednarz, and Gelareh Mohammadi. Virtual reality for emotion elicitation – a review, 2021.
- [6] Daniel Martin, Sandra Malpica, Diego Gutierrez, Belen Masia, and Ana Serrano. Multimodality in vr: A survey, 2022.
- [7] Panagiotis Kourtesis. A comprehensive review of multimodal xr applications, risks, and ethical challenges in the metaverse, 2024.
- [8] Haseeb ur Rahman Abbasi, Zeeshan Rashid, Muhammad Majid, and Syed Muhammad Anwar. Human emotions analysis and recognition using eeg signals in response to 360° videos, 2024.
- [9] Thiago Porcino, Esteban Clua, Daniela Trevisan, Érick Rodrigues, and Alexandre Silva. Automatic recommendation of strategies for minimizing discomfort in virtual environments, 2020.
- [10] Seraphina Yong, Leo Cui, Evan Suma Rosenberg, and Svetlana Yarosh. A change of scenery: Transformative insights from retrospective vr embodied perspective-taking of conflict with a close other, 2024.
- [11] Alexandra Kitson. Investigating the feasibility of virtual reality for emotion regulation with youth, 2022.
- [12] Rukshani Somarathna and Gelareh Mohammadi. Exploring emotions in multi-componential space using interactive vr games, 2024.
- [13] Alice Good and Arunasalam Sambhathan. A review into ehealth services and therapies: Potential for virtual therapeutic communities - supporting people with severe personality disorder, 2013.
- [14] He Zhang and John M. Carroll. Exploring virtual reality through ihde’s instrumental realism, 2024.
- [15] Julian Rasch, Michelle Johanna Zender, Sophia Sakel, and Nadine Wagener. Mind mansion: Exploring metaphorical interactions to engage with negative thoughts in virtual reality, 2024.
- [16] Yixuan Wu, Kaiyuan Hu, Danny Z. Chen, and Jian Wu. Ai-enhanced virtual reality in medicine: A comprehensive survey, 2024.
- [17] Syed Ali Asif, Philip Gable, Chien-Chung Shen, and Yan-Ming Chiou. Understanding emotional hijacking in metaverse, 2024.
- [18] Sunday David Ubur and Denis Gracanin. Narrative review of support for emotional expressions in virtual reality: Psychophysiology of speech-to-text interfaces, 2024.
- [19] Annual reviews.
- [20] Radiah Rivu, Ville Mäkelä, Sarah Prange, Sarah Delgado Rodriguez, Robin Piening, Yumeng Zhou, Kay Köhle, Ken Pfeuffer, Yomna Abdelrahman, Matthias Hoppe, Albrecht Schmidt, and Florian Alt. Remote vr studies – a framework for running virtual reality studies remotely via participant-owned hmds, 2021.

-
- [21] Omer Aydin, Enis Karaarslan, and Nida Gokce Narin. Artificial intelligence, vr, ar and metaverse technologies for human resources management, 2024.
- [22] Mi Jin Park, Dong Jun Kim, Unjoo Lee, Eun Jin Na, and Hong Jin Jeon. A literature overview of virtual reality (vr) in treatment of psychiatric disorders: recent advances and limitations. *Frontiers in psychiatry*, 10:505, 2019.
- [23] Sam Van Damme, Maria Torres Vega, and Filip De Turck. Human-centric quality management of immersive multimedia applications. In *2020 6th IEEE Conference on Network Softwarization (NetSoft)*, pages 57–64. IEEE, 2020.
- [24] Daniel H. Lee and Tzyy-Ping Jung. A virtual reality game as a tool to assess physiological correlations of stress, 2020.
- [25] Dmitry Alexandrovsky, Susanne Putze, Valentin Schwind, Elisa D. Mekler, Jan David Smeddinck, Denise Kahl, Antonio Krüger, and Rainer Malaka. Evaluating user experiences in mixed reality, 2021.
- [26] Ying Choon Wu, Christopher Maymon, Jonathon Paden, and Weichen Liu. Launching your vr neuroscience laboratory, 2024.
- [27] David R. Glowacki, Mark D. Wonnacott, Rachel Freire, Becca R. Glowacki, Ella M. Gale, James E. Pike, Tiu de Haan, Mike Chatziapostolou, and Oussama Metatla. Isness: Using multi-person vr to design peak mystical-type experiences comparable to psychedelics, 2020.
- [28] Yi Li, Zengyu Liu, Xiandi Zhu, and Ning Xie. Zeitgebers-based user time perception analysis and data-driven modeling via transformer in vr, 2024.
- [29] Y Pawan Kumar Gururaj, Raghav Mittal, Sai Anirudh Karre, Y. Raghu Reddy, and Syed Azeemuddin. Towards conducting effective locomotion through hardware transformation in head-mounted-device – a review study, 2023.
- [30] Panagiotis Kourtesis, Josie Linnell, Rayaam Amir, Ferran Argelaguet, and Sarah E. MacPherson. Cybersickness in virtual reality questionnaire (csq-vr): A validation and comparison against ssq and vrsq, 2023.
- [31] S. M. Hossein Mousavi, Matteo Besenzoni, Davide Andreoletti, Achille Peternier, and Silvia Giordano. The magic xroom: A flexible vr platform for controlled emotion elicitation and recognition, 2024.
- [32] Zeeshan Ahmad, Suha Rabbani, Muhammad Rehman Zafar, Syem Ishaque, Sridhar Krishnan, and Naimul Khan. Multi-level stress assessment from ecg in a virtual reality environment using multimodal fusion, 2021.
- [33] Lisa May Thomas, Helen M. Deeks, Alex J. Jones, Oussama Metatla, and David R. Glowacki. Somatic practices for understanding real, imagined, and virtual realities, 2019.
- [34] Israel Becerra, Markku Suomalainen, Eliezer Lozano, Katherine J. Mimnaugh, Rafael Murrieta-Cid, and Steven M. LaValle. Human perception-optimized planning for comfortable vr-based telepresence, 2020.
- [35] Maximilian Warsinke, Tanja Kojić, Maurizio Vergari, Robert Spang, Jan-Niklas Voigt-Antons, and Sebastian Möller. Comparing continuous and retrospective emotion ratings in remote vr study, 2024.
- [36] Fatemeh Dehghani and Loutfouz Zaman. Facial emotion recognition in vr games, 2023.
- [37] Panagiotis Kourtesis and Sarah E. MacPherson. Immersive virtual reality methods in cognitive neuroscience and neuropsychology: Meeting the criteria of the national academy of neuropsychology and american academy of clinical neuropsychology, 2021.
- [38] Junyi Shen, Itaru Kitahara, Shinichi Koyama, and Qiaoge Li. Size does matter: An experimental study of anxiety in virtual reality, 2022.
- [39] Panagiotis Kourtesis, Simona Collina, Leonidas A. A. Doulas, and Sarah E. MacPherson. Validation of the virtual reality neuroscience questionnaire: Maximum duration of immersive virtual reality sessions without the presence of pertinent adverse symptomatology, 2021.

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