Review Article

Immersive Interventions for Dementia: A Narrative Review of Virtual Reality's Role in Therapy, Well-Being, and Future Care Models

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Abstract: Dementia is a progressive neurocognitive disorder frequently accompanied by behavioral and psychological symptoms such as agitation, anxiety, and depression, which substantially affect the quality of life for patients and caregivers. Pharmacological treatments remain widely used but offer limited efficacy and pose significant safety concerns, underscoring the need for effective non-pharmacological alternatives. This narrative review examines the role of virtual reality (VR) in dementia care, intending to synthesize current evidence on its therapeutic applications, implementation challenges, and future integration into care models. A structured narrative synthesis was conducted across studies published between 2015 and 2024, focusing on VR-based music therapy, reminiscence therapy, sensory stimulation, cognitive training, and home-based interventions. The reviewed evidence indicates that VR interventions demonstrate moderate efficacy for cognitive outcomes, with the most consistent benefits observed in memory-related domains and anxiety reduction through reminiscence-based approaches that engage preserved autobiographical and emotional memory systems. Adaptive VR music therapy further shows promise in reducing frustration and enhancing engagement. Importantly, the findings challenge the assumption that higher immersion uniformly yields greater benefit; instead, therapeutic effectiveness reflects trade-offs between immersion level, usability, cognitive load, and patient capacity, with semi-immersive systems often offering a pragmatic balance. Despite encouraging outcomes, significant challenges remain, including usability barriers, limited acceptance of technology, limited long-term and economic evidence, and underrepresentation of diverse cultural and socioeconomic contexts. This review extends existing literature by critically synthesizing mechanisms, trade-offs, and implementation considerations while distinguishing robust evidence from preliminary findings. Overall, VR represents a promising adjunct in dementia care, but its transition from experimental application to evidence-based practice will require rigorous longitudinal research, standardized reporting, and equitable, user-centered implementation strategies.

Keywords: Caregiver Support; Cognitive Rehabilitation; Dementia Care; Non-Pharmacological Interventions; Quality of Life; Reminiscence Therapy; Sustainable Healthcare; Virtual Reality.

1. Introduction

Dementia affects more than 57 million people worldwide, leading to progressive impairments in memory, judgment, and emotional regulation, while placing substantial burdens on patients, caregivers, and healthcare systems [1]–[3]. Although pharmacological treatments remain the standard of care, their therapeutic benefits are often modest and accompanied by notable safety concerns, particularly in older adults, underscoring the need for safer and more sustainable non-pharmacological alternatives [3]–[5].

Recent systematic and meta-analytic reviews have reported moderate evidence supporting the use of virtual reality (VR)–based interventions for improving cognitive outcomes in individuals with dementia and mild cognitive impairment [6]–[8]. However, several important gaps remain insufficiently addressed. First, prior reviews have largely emphasized cognitive

performance, with comparatively limited attention to behavioral and psychological symptoms of dementia (BPSD), emotional well-being, caregiver burden, and broader quality-of-life outcomes [6], [9]. Second, the majority of existing evidence originates from high-income settings, limiting understanding of the feasibility and effectiveness of VR interventions across diverse cultural and resource-constrained contexts [8], [10]. Third, safety and tolerability issues, including cybersickness and sensory overload in older populations, have not been examined consistently across studies [10], [11]. Fourth, there remains an inadequate synthesis of trade-offs between different levels of immersion, usability, and therapeutic benefit [8], [12]. Finally, emerging developments such as AI-driven personalization, home-based VR delivery, and integration with biometric feedback have not yet been systematically contextualized within the dementia care literature [13].

In response to these gaps, this narrative review provides an integrated synthesis of recent evidence on immersive VR interventions in dementia care, extending beyond cognitive outcomes to encompass BPSD management, emotional well-being, caregiver support, implementation challenges, cost considerations, and accessibility barriers. Drawing on studies published between 2015 and 2024, including adaptive music therapy with EEG feedback, home-based VR protocols, and culturally adapted interventions, this review aims to clarify the evolving role of VR across the dementia care continuum. By synthesizing findings across therapeutic, technological, and contextual dimensions, the review seeks to inform evidence-based clinical decision-making and highlight priorities for future research.

The remainder of this paper is structured as follows. Section 2 outlines the review methodology. Section 3 introduces key background concepts and theoretical frameworks underpinning VR-based dementia interventions. Section 4 reviews major application domains and reported outcomes, while Section 5 examines practical challenges related to usability, acceptance, and implementation. Section 6 discusses issues of cost-effectiveness, accessibility, and equity. Section 7 provides a critical synthesis of cross-study patterns, mechanisms, trade-offs, and clinical implications, and Section 8 concludes with key insights and future research directions.

2. Methodology

2.1. Review Design and Objectives

This study was a narrative review that synthesized current evidence on the role of immersive VR interventions in dementia care. The review focuses on therapeutic applications, impacts on well-being, and the potential integration of VR into future care models. Specifically, it aims to provide an overview of VR-based approaches for managing behavioral and psychological symptoms of dementia (BPSD), supporting cognitive function, and improving quality of life, while also identifying methodological limitations, research gaps, and emerging directions in this rapidly evolving field.

2.2. Search Strategy and Information Sources

A comprehensive literature search was carried out across multiple electronic databases, including PubMed, Google Scholar, IEEE Xplore, and Web of Science. The search targeted peer-reviewed journal articles, conference proceedings, systematic reviews, and meta-analyses published primarily between 2016 and 2024. Search queries combined relevant keywords and phrases such as "virtual reality," "VR," "immersive technology," "dementia," "Alzheimer's disease," "mild cognitive impairment," "MCI," "reminiscence therapy," "music therapy," "cognitive training," "behavioral and psychological symptoms," "BPSD," "quality of life," and "non-pharmacological interventions." Boolean operators (AND, OR) were applied to refine the search and ensure coverage across therapeutic modalities and technological implementations.

2.3. Inclusion and Exclusion Criteria

Studies were included if they met the following criteria: (1) publication in English-language, peer-reviewed journals or conference proceedings; (2) focus on individuals diagnosed with dementia, mild cognitive impairment, or related neurocognitive disorders; (3) evaluation of VR interventions at any level of immersion (non-immersive, semi-immersive, or fully immersive); (4) reporting outcomes related to cognitive function, behavioral symptoms,

emotional well-being, quality of life, or usability; and (5) use of quantitative, qualitative, or mixed-methods designs, including randomized controlled trials, pilot studies, feasibility studies, systematic reviews, and meta-analyses.

Studies were excluded if they: (1) examined non-VR technologies without immersive components (e.g., tablet-based applications); (2) were conducted exclusively using animal models; (3) lacked sufficient methodological detail or clarity in outcome reporting; (4) were published solely as abstracts, editorials, or opinion pieces without empirical data; or (5) did not address dementia or cognitive impairment as a primary focus.

2.4. Study Selection and Data Synthesis

The initial database search yielded a broad set of potentially relevant publications. Titles and abstracts were screened to assess eligibility based on the predefined inclusion and exclusion criteria. Full-text versions of potentially eligible studies were then reviewed in detail. Ultimately, 22 primary sources were included in this narrative review, comprising empirical studies, systematic reviews, and meta-analyses that collectively reflect the current state of knowledge on VR interventions in dementia care.

Given the heterogeneity across study designs, VR technologies (e.g., head-mounted displays and projection-based systems), intervention types (e.g., music therapy, reminiscence therapy, cognitive training), outcome measures, and patient populations, a narrative synthesis approach was adopted rather than a quantitative meta-analysis. Data were organized thematically around key domains, including VR applications and outcomes, implementation challenges, theoretical frameworks, cost-effectiveness, and future research directions. Findings were compared and contrasted to identify common patterns, consistent effects, areas of divergence, and remaining gaps in the literature.

2.5. Quality Appraisal and Limitations

Although formal quality appraisal tools were not systematically applied to all included studies, attention was paid to study design rigor, sample size, reporting transparency, and the overall strength of evidence when interpreting the findings. It is acknowledged that a substantial proportion of the included literature consists of pilot or feasibility studies with small samples and short follow-up periods, which limits generalizability. The review is also subject to potential publication bias, as studies reporting positive outcomes are more likely to be published. Furthermore, restricting inclusion to English-language publications may have resulted in the omission of relevant studies published in other languages. These limitations are considered in the discussion and implications presented later in the paper.

3. Background

3.1. Dementia's Global Burden and Challenges

Dementia affects approximately 57.4 million individuals worldwide, with prevalence projected to rise to 152.8 million by 2050, particularly in low- and middle-income countries [14]. This progressive neurocognitive disorder encompasses conditions such as Alzheimer's disease, Lewy body dementia, and vascular dementia, all of which impair memory, reasoning, language, and emotional regulation, ultimately reducing functional independence [1], [3]. Beyond cognitive decline, behavioral and psychological symptoms of dementia (BPSD)—including agitation, depression, anxiety, apathy, and sleep disturbances—substantially complicate clinical management, increase caregiver burden, and frequently contribute to institutionalization [2], [4].

The societal impact of dementia extends well beyond healthcare systems. Informal caregivers often experience elevated levels of depression, anxiety, physical health problems, and financial strain due to reduced employment and ongoing care-related expenses [15]. Globally, dementia-related care costs exceeded USD 1.3 trillion in 2019 and continue to rise sharply as populations age [16]. The combination of increasing prevalence, high economic burden, and the complex management of BPSD underscores the need for interventions that not only address symptoms but also prioritize patient well-being and caregiver support within sustainable care models [3], [4], [15].

3.2. Limitations and Risks of Pharmacological Treatments

Pharmacological approaches remain widely used to manage BPSD, yet their effectiveness is limited and is accompanied by substantial safety concerns [5]. Atypical antipsychotics, such as olanzapine and risperidone, may provide modest short-term symptom relief; however, accumulating evidence demonstrates increased risks of mortality, pneumonia, cerebrovascular events, Parkinsonian symptoms, and venous thromboembolism, even with relatively brief treatment durations [17]. These findings have reinforced longstanding concerns regarding the routine use of antipsychotics in dementia care.

Similarly, benzodiazepines and Z-drugs are frequently prescribed for sleep disturbances and agitation in dementia but are now strongly associated with falls, pneumonia, hospitalizations, dependence, and elevated mortality, particularly in Alzheimer's disease populations [18]. Sleep disturbances affect up to 60% of individuals with dementia [19] and are often managed pharmacologically; however, recent population-based studies indicate that cumulative exposure to benzodiazepines and Z-drugs is associated with an increased risk of developing dementia [19]. Together with their well-documented adverse effects—such as sedation, dependence, and fall risk—these findings raise serious concerns regarding long-term use in older adults [18].

Beyond medications targeting BPSD, cholinesterase inhibitors and memantine—the primary drugs approved for cognitive symptoms—offer only modest and time-limited benefits [20]. These agents do not modify disease progression, and symptomatic improvements often diminish within months to years after initiation [20]. Collectively, the limited efficacy and substantial risks associated with pharmacological strategies highlight the need for complementary non-pharmacological interventions capable of managing symptoms without compromising patient safety [4], [5], [19], [21].

3.3. Principles of VR Technology in Therapeutic Contexts

Virtual reality (VR) refers to technology that creates immersive, digitally simulated environments, typically accessed through head-mounted displays or large projection systems, allowing users to interact with lifelike settings in a controlled manner [22]. Although initially developed for entertainment, VR has increasingly been adopted in medical contexts, including surgical training, physical rehabilitation, psychological therapy, and pain management [22], [23].

In dementia care, VR enables the delivery of multisensory experiences that can be tailored to individual cognitive capacities, emotional states, and personal histories, offering a level of environmental control and repeatability that is difficult to achieve using conventional interventions [4], [22]–[24]. Importantly, VR systems differ substantially in their level of immersion. Fully immersive VR typically relies on head-mounted displays that replace the user's field of view with computer-generated imagery and may incorporate spatial audio and motion tracking. Semi-immersive systems use large screens or projection-based environments that partially surround the user, while non-immersive VR includes desktop or tablet-based applications presented on conventional displays [12], [24].

Each immersion level involves trade-offs related to presence, engagement, cognitive load, cost, and usability. For older adults with cognitive impairment, these trade-offs are particularly salient, as higher immersion may enhance engagement but also increase the risk of discomfort or cognitive overload if not carefully designed [12], [24].

3.4. Non-Pharmacological Interventions and VR Enhancement

Non-pharmacological interventions constitute evidence-based approaches that engage cognitive, emotional, and sensory processes to manage BPSD while avoiding the adverse effects associated with pharmacological treatments [3], [4]. Such interventions have demonstrated effectiveness in reducing agitation and depression and in improving quality of life and cognitive function in dementia populations [25].

Reminiscence therapy facilitates discussion of past experiences through prompts such as photographs, music, familiar objects, or reconstructed environments, leveraging relatively preserved autobiographical memory systems to promote emotional connection and cognitive engagement [22], [25]. Music therapy, defined as the clinical use of music interventions by trained professionals, supports memory, mood, and communication by activating preserved musical memory networks and eliciting emotional responses [26]. Sensory stimulation

interventions engage modalities such as sight, sound, touch, and smell to encourage interaction and reduce behavioral symptoms as cognitive abilities decline, ranging from structured multisensory environments to nature-based approaches [25], [27].

VR enhances these established interventions by enabling immersive, multisensory environments that offer greater engagement, personalization, and experimental control than traditional formats [4], [22], [27], [28]. For example, VR-based reminiscence therapy can recreate childhood homes, meaningful locations, or historical periods with rich contextual detail [22], [24]. VR music therapy can place individuals in interactive concert environments or in personalized soundscapes synchronized with visual stimuli [29]. Similarly, VR-based sensory stimulation can simulate natural settings—such as beaches, forests, or gardens—providing therapeutic exposure to environments that may otherwise be inaccessible due to mobility or safety constraints [25], [27]. The adaptability of VR allows rapid customization to individual preferences, cultural contexts, and cognitive capacities, supporting person-centered intervention design [24], [25].

3.5. Theoretical Models Supporting VR in Dementia Care

Several theoretical frameworks underpin the application of VR in dementia care and inform intervention design [4], [30]. Cognitive stimulation theory proposes that structured activities that engage memory, attention, and problem-solving can help maintain cognitive function, slow cognitive decline, and reduce BPSD by enhancing cognitive reserve and promoting neuroplasticity [4], [31]. Sensory integration theory emphasizes the role of multisensory input in facilitating neural processing, emotional regulation, attention, and social interaction by simultaneously activating multiple sensory pathways [30], [31].

VR aligns closely with these models by providing controlled, multisensory environments that elicit both cognitive and emotional responses [4], [30]. Virtual environments can evoke autobiographical memories through familiar visual and auditory cues, stimulate emotional processing via personally meaningful content, and present interactive tasks calibrated to an individual's cognitive capacity [30], [31]. By integrating visual, auditory, and, in some systems, tactile stimuli within coherent and meaningful contexts, VR supports neural engagement in ways that are difficult to replicate through traditional non-pharmacological approaches [30], [31].

In addition, the concept of presence—defined as the subjective sense of "being there" in a virtual environment—plays a central role in VR's therapeutic mechanisms [24], [32]. Higher levels of presence have been associated with increased emotional engagement, sustained attention, and more robust cognitive processing, all of which may enhance therapeutic outcomes [32]. However, achieving optimal presence requires careful balancing of immersion, usability, and cognitive load, particularly for individuals with cognitive impairment who may be overwhelmed by overly complex or intense virtual experiences [12], [24], [32].

4. Applications and Outcomes of VR in Dementia Care

This section reviews applications of VR in dementia care across music and sensory therapies, reminiscence therapy, cognitive training, and home-based protocols. The presentation emphasizes therapeutic modalities and observed outcomes, while avoiding detailed repetition of experimental procedures.

4.1. VR Music and Sensory Therapies

VR-enhanced music therapy integrates personalized musical selections with immersive visual environments to support emotional regulation and cognitive engagement in individuals with dementia. By combining auditory and visual stimuli within controlled virtual settings, these interventions aim to leverage relatively preserved emotional and autobiographical memory systems while reducing behavioral distress. Recent systems incorporate adaptive mechanisms, such as EEG-based emotional monitoring, enabling real-time adjustment of visual and auditory content in response to users' affective states (Figure 1) [29].

As illustrated in Figure 1 [29], the VR music therapy system supports adaptive visual–auditory configurations aligned with different therapeutic objectives. The left panel depicts a visually softer, less intense environment, typically paired with calming music to promote relaxation and reduce agitation, whereas the right panel presents a more vivid, dynamic visual configuration, synchronized with more upbeat musical selections to enhance engagement and

positive affect. This adaptive pairing enables modulation of stimulation intensity according to individual emotional states and therapeutic goals.

Figure 1. Examples of adaptive virtual music therapy environments: (**left**) a lower-intensity visual configuration; (**right**) a higher-intensity and more dynamic visual configuration [29].

Quantitative outcomes demonstrate a consistent reduction in frustration levels following VR music therapy. Mean frustration scores decreased from 0.69 prior to intervention to 0.45 during VR exposure and remained below baseline at 0.51 after therapy (Figure 2) [29]. These results indicate that immersive music-based VR can effectively attenuate negative emotional states, particularly during active engagement.

As shown in Figure 2 [29], the distribution of frustration scores exhibits a marked reduction during VR immersion, with post-therapy values remaining lower than pre-intervention levels. The relatively narrow interquartile ranges suggest comparable responses across participants, supporting the robustness of the observed emotional effects.
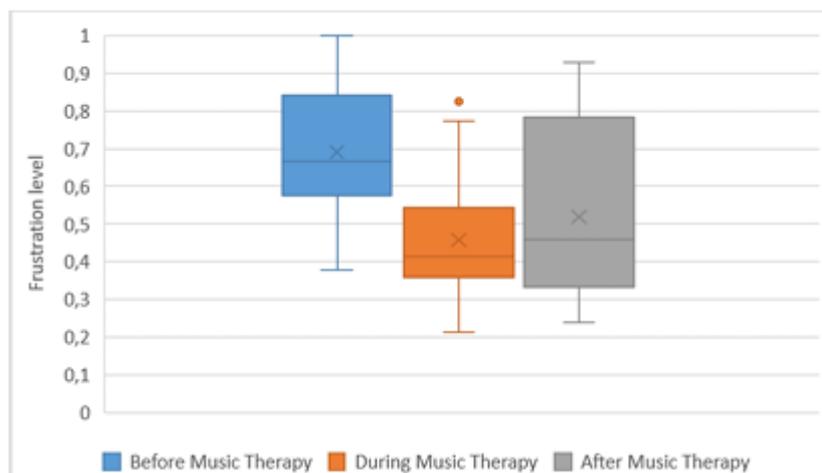

Figure 2. Frustration levels before, during, and after VR music therapy [29].

Cognitive outcomes reveal domain-specific effects. Memory performance improved substantially, with reported gains ranging from 6% to 37%, whereas attention-related tasks showed minimal or inconsistent changes (Figure 3) [29]. This dissociation suggests that VR music therapy preferentially engages preserved autobiographical and emotional memory networks rather than attentional control processes, which are often more severely impaired in dementia.

As illustrated in Figure 3 [29], improvements in memory tasks clearly exceed those observed in attention-based exercises, with several participants demonstrating pronounced memory gains. This pattern aligns with prior evidence indicating that music- and emotion-centered interventions are particularly effective in supporting memory-related outcomes in dementia populations.
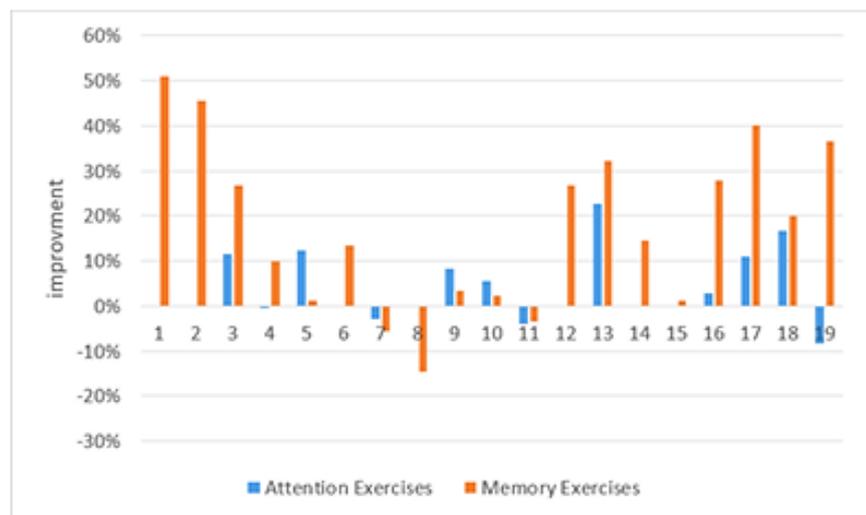
Figure 3. Comparison of attention and memory performance changes after VR music therapy.

These findings are consistent with broader literature showing that VR-based interventions can reduce behavioral and psychological symptoms of dementia, particularly affective symptoms such as frustration and depression, while producing mixed effects across other BPSD domains [33]. By combining emotional engagement with immersive multisensory stimulation, VR-enhanced music therapy offers advantages over traditional approaches. It represents a promising adjunctive non-pharmacological intervention, free of the safety risks associated with pharmacological treatments [29], [33].

4.2. VR-Enhanced Reminiscence Therapy

VR-enhanced reminiscence therapy leverages immersive virtual environments to recreate culturally meaningful and personally familiar contexts, intending to reduce anxiety and support emotional well-being in individuals with dementia. By simulating emotionally salient past experiences, this approach seeks to activate relatively preserved autobiographical memory and emotional processing pathways, thereby alleviating behavioral and psychological symptoms without pharmacological intervention.

A pilot study involving 10 older adults with dementia (mean age: 87.1 years) examined the effects of VR reminiscence therapy using Japanese Showa-era environments [34]. Anxiety outcomes were assessed using the State–Trait Anxiety Inventory (STAI) before VR exposure, after the first VR session, and after the second VR session. Results demonstrated a progressive reduction in total STAI scores, decreasing from a baseline mean of 36.1 to 26.8 following the first session and further to 23.4 after the second session (P < 0.001), indicating a robust reduction in anxiety levels over repeated exposure (Figure 4) [34].

As illustrated in Figure 4, reductions were more pronounced for the anxiety-present (state anxiety) subscale than for the anxiety-absent (trait anxiety) subscale. This pattern suggests that VR reminiscence therapy primarily influences current emotional state rather than long-standing anxiety traits, which is consistent with the intervention's emphasis on emotionally engaging, context-specific experiences [34].

Participants also evaluated content preferences and subjective experience. Photorealistic live-action (LA) VR content was rated more favorably than computer-generated (CG) environments, with mean satisfaction scores of 8.6 versus 7.0, respectively. However, the difference did not reach statistical significance (P = 0.0993) [34]. Anxiety improvements were most pronounced following the initial VR exposure and were largely maintained across subsequent sessions, indicating sustained therapeutic effects rather than transient novelty responses (Figure 5).

As shown in Figure 5, reductions in STAI scores were observed across all participants and within both experimental groups (Groups A and B), regardless of whether live-action or computer-generated content was presented first. The parallel trends across groups suggest that the anxiolytic effects of VR reminiscence therapy were consistent and not strongly dependent on content presentation order, supporting the robustness of the intervention [34].
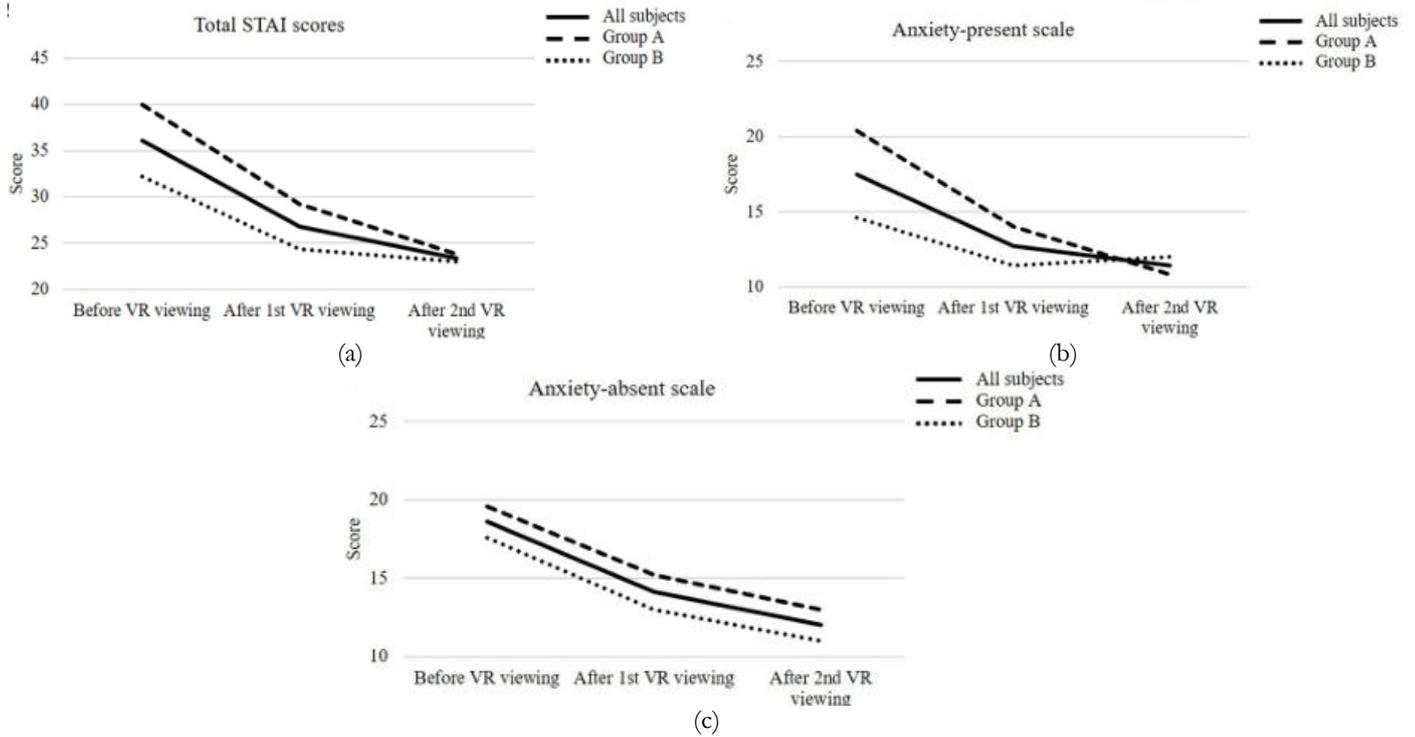
Figure 4. Changes in State–Trait Anxiety Inventory (STAI) scores across VR reminiscence therapy sessions: (**a**) total STAI scores, (**b**) anxiety-present (state anxiety) subscale, and (**c**) anxiety-absent (trait anxiety) subscale, measured before VR exposure, after the first VR session, and after the second VR session for all participants and for Groups A and B [34].
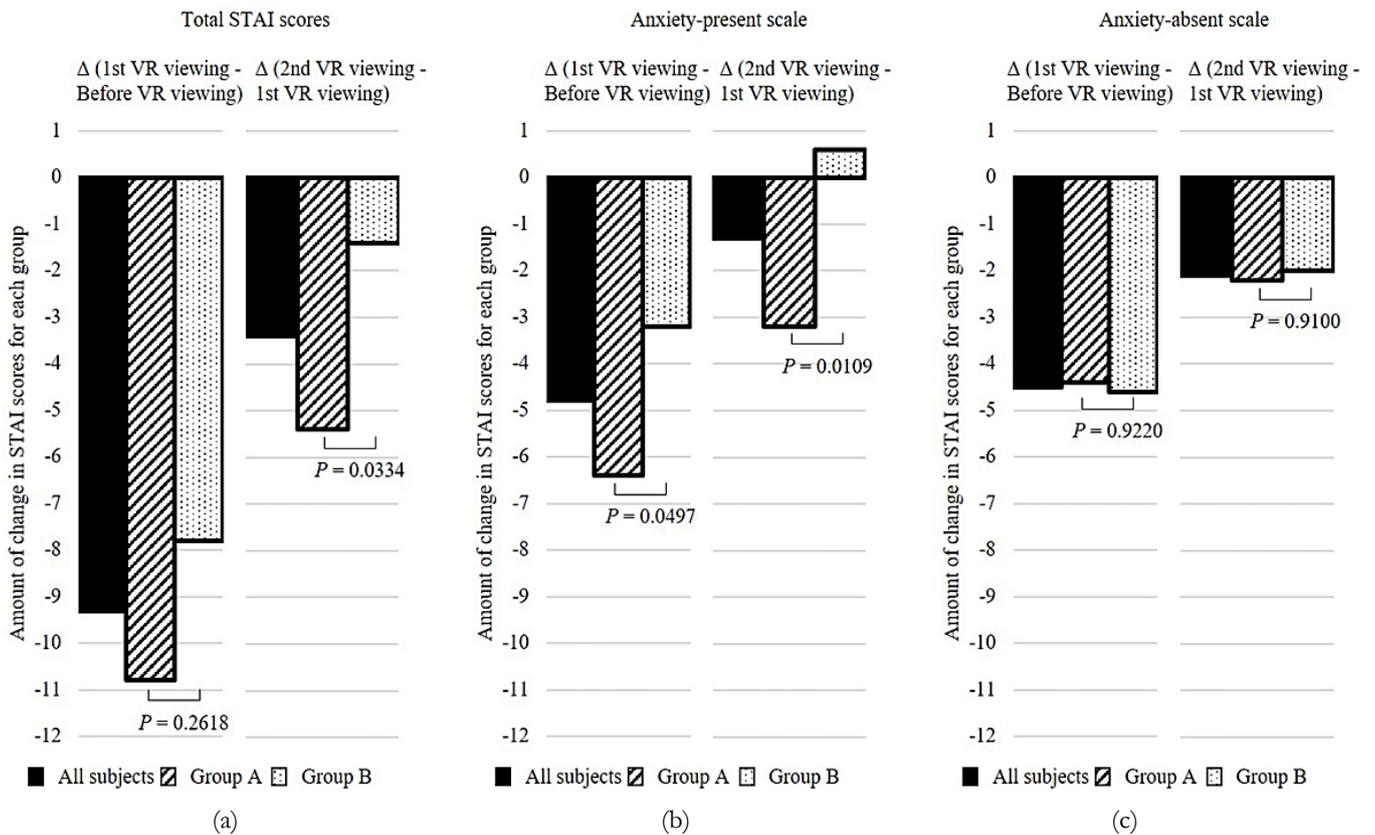

Figure 5. Session-to-session changes in STAI scores: (A) total score, (B) anxiety-present subscale, and (C) anxiety-absent subscale for all participants and Groups A and B [34].

Safety and tolerability were systematically evaluated, with particular attention to symptoms commonly associated with immersive VR use in older populations. As summarized in Table 1, no serious adverse effects, such as nausea or dizziness, were reported following VR exposure. Mild transient tiredness was observed in a small number of participants, but no statistically significant differences were detected between groups or across sessions [34].

Table 1. Participant satisfaction and side effects following VR viewing in Group A and Group B [34].

Outcome	Group A (n = 5) After 1st VR (CG)	Group A After 2nd VR (LA)	P-value	Group B (n = 5) After 1st VR (LA)	Group B After 2nd VR (CG)	P-value
Satisfaction [mean (SD, range)]	7.0 [2.3 (5–10)]	8.6 [1.5 (7–10)]	0.0993	8.6 [2.2 (5–10)]	8.2 [1.9 (5–10)]	0.1778
Nausea [mean (SD, range)]	0.2 [0.4 (0–1)]	0.0 [0.0 (0–0)]	0.3739	0.0 [0.0 (0–0)]	0.0 [0.0 (0–0)]	N/A
Dizziness [mean (SD, range)]	0.0 [0.0 (0–0)]	0.0 [0.0 (0–0)]	N/A	0.0 [0.0 (0–0)]	0.0 [0.0 (0–0)]	N/A
Headache [mean (SD, range)]	0.2 [0.4 (0–1)]	0.2 [0.4 (0–1)]	N/A	0.0 [0.0 (0–0)]	0.0 [0.0 (0–0)]	N/A
Tiredness [mean (SD, range)]	0.8 [1.3 (0–3)]	0.0 [0.0 (0–0)]	0.2420	0.2 [0.4 (0–1)]	0.2 [0.4 (0–1)]	N/A

The absence of serious adverse effects, together with consistently high satisfaction ratings, indicates that VR-enhanced reminiscence therapy is well tolerated, even among the oldest-old. These findings support its suitability as a scalable digital therapeutic approach, particularly for home-based or remote dementia care settings where access to conventional in-person interventions may be limited [34], [35]. By reducing anxiety and other behavioral and psychological symptoms without the risks associated with pharmacological treatments, VR-based reminiscence therapy can serve as a non-pharmacological adjunct within comprehensive dementia care strategies [33], [34].

4.3. VR for Physical and Cognitive Training

VR-based physical and cognitive training interventions offer immersive, interactive tasks designed to target attention, working memory, executive function, and motor coordination. By embedding training activities within ecologically valid and culturally familiar virtual environments, these systems aim to promote engagement while reducing the abstraction often associated with conventional computer-based cognitive exercises.
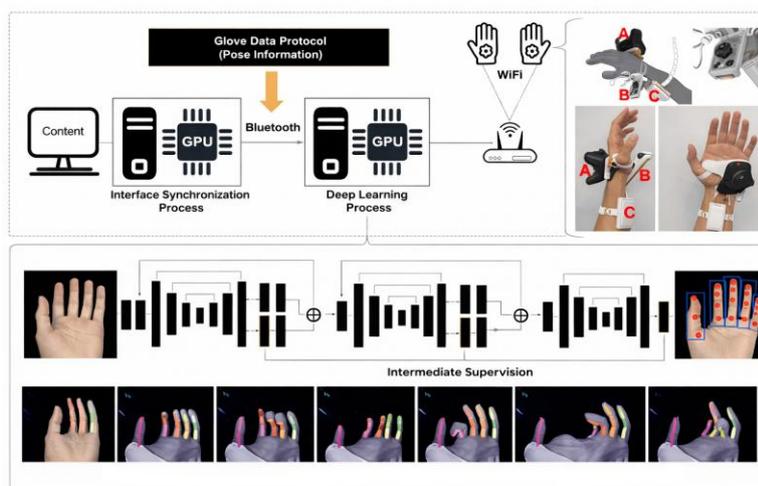

Figure 6. System design of the hand pose estimation module for VR-based cognitive training [36].

A pilot study involving 11 individuals with mild cognitive impairment or early-stage dementia (MMSE 23–28; CDR 0.5–1) evaluated a VR-based cognitive training system set in culturally adapted Korean rural environments [36]. The intervention employed natural hand gestures to perform everyday activities, such as harvesting crops and cooking traditional meals, thereby minimizing reliance on handheld controllers and lowering technological barriers for older adults (Figures 6–8).

The system architecture is illustrated in Figure 6, which depicts the hand pose estimation module used to capture and interpret natural hand movements. The system integrates a

motion-tracking component for three-dimensional hand pose detection, a camera-based module for visual input to gesture recognition, and a transmission and power management unit. This configuration enables direct interaction with virtual objects through intuitive hand gestures, supporting more naturalistic motor engagement during training tasks [36].

The virtual environments used in the intervention are shown in Figure 7. Standard scenes include a main environment representing a traditional Korean rural village and farmhouse, which serves as the setting for harvesting and cooking activities and as an interface for entering patient information. The latter allows clinicians to adjust task difficulty and monitor individual progress across sessions, supporting personalized intervention delivery [36].

Figure 7. Standard VR scenes for cognitive training and patient information input: (**a**) a main scene depicting a typical Korean rural village and farmhouse for harvesting and cooking activities, providing familiar cultural context that may enhance engagement and emotional connection, and (**b**) a scene for entering patient information, allowing clinicians to customize difficulty levels and track individual progress across sessions [36].

Task-specific interactions are illustrated in Figure 8, which presents a sequence of harvesting and cooking activities. Participants engage in multiple subtasks, including collecting crops from different farm plots, gathering eggs, and preparing familiar dishes such as fried eggs, gimbap, and soybean paste stew. Harvesting tasks primarily emphasize sustained attention and visuomotor coordination, whereas multi-step cooking activities engage working memory, sequencing, and executive planning. The diversity of task demands allows therapists to target multiple cognitive domains within a single intervention framework [36].
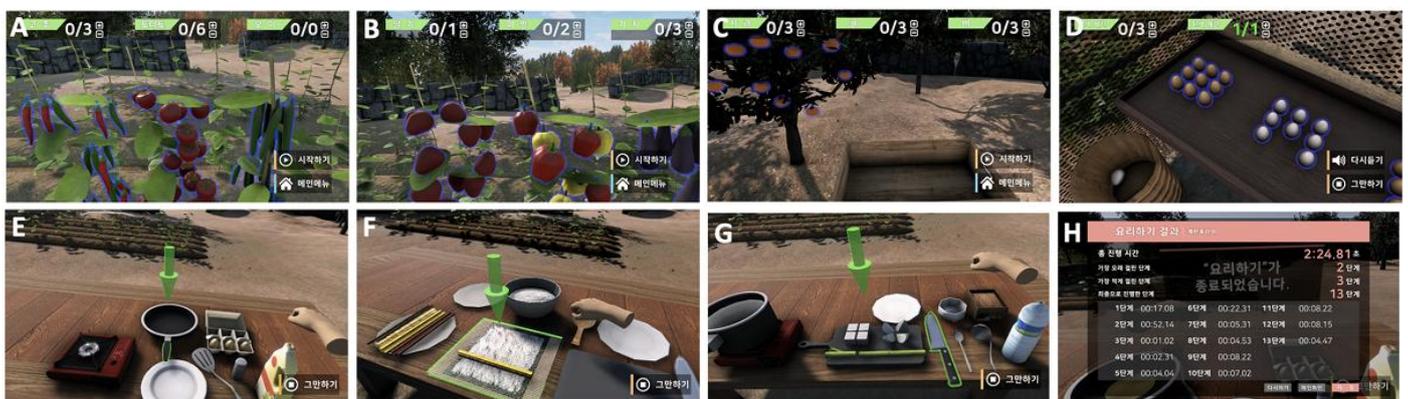

Figure 8. The harvest and cook game features: (**a**) farm A with chilis, tomatoes and cucumbers; (**b**) farm B with strawberries, paprika and eggplants; (**c**) an orchard with apples, mandarins and pears; (**d**) a hen house with brown and white eggs; (**e**) fried eggs; (**f**) gimbap (dried seaweed roll); (**g**) soybean paste stew; and (**h**) the outcomes of the cooking game. The diversity of tasks allows therapists to target different cognitive domains. Harvesting emphasizes attention and visuomotor coordination, while multi-step cooking recipes engage working memory, sequential planning, and executive function [36].

Participants reported high levels of satisfaction (patients: 5.64/7; specialists: 5.75/7), positive mood effects (6.18/7), and physical comfort (6.91/7), with no reports of motion sickness [36]. Behavioral measures showed a non-significant reduction in response time from 612 ms to 547 ms (P = 0.25), alongside preserved motor performance, indicating that the intervention was well tolerated without compromising motor function [36].

Beyond pilot-scale studies, meta-analytic evidence from 11 randomized controlled trials demonstrates that VR interventions produce moderate effect sizes across several cognitive and motor domains [37]. As summarized in Figure 9, pooled results indicate significant improvements in overall cognition (Hedges' $g = 0.45$, $P < 0.001$), attention ($g = 0.49$, $P < 0.001$), and memory ($g = 0.57$, $P < 0.001$), while effects on visuospatial ability were not statistically significant. These findings suggest that VR-based cognitive training is particularly effective for domains involving attention and memory processes [37].
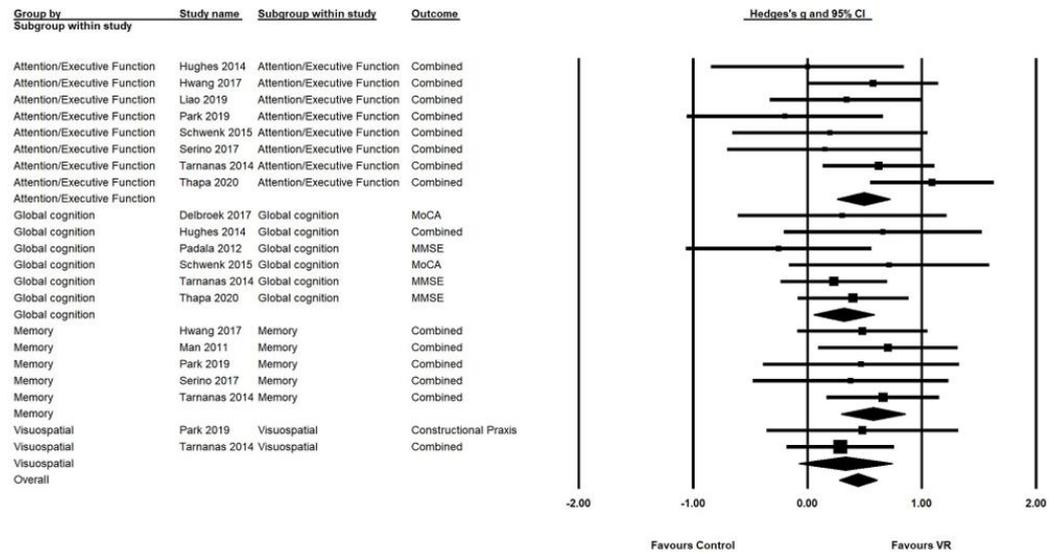

Figure 9. Forest plot of cognitive outcomes comparing VR interventions with control conditions [37].

Motor outcomes are summarized in Figure 10, which shows that VR interventions yield moderate improvements in balance ($g = 0.43$, $P = 0.02$) but do not produce significant effects on gait [37]. This dissociation may reflect the nature of VR tasks commonly employed, which often emphasize weight shifting, postural control, and static balance rather than continuous locomotion, which may require more specialized treadmill-based or gait-specific VR systems.
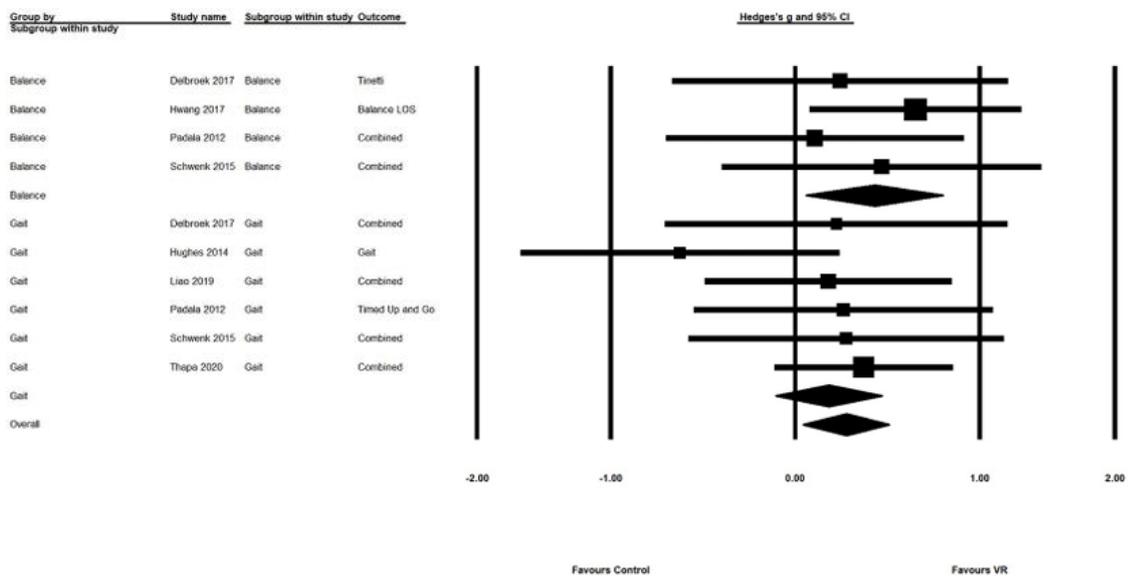

Figure 10. Forest plot of motor outcomes (balance and gait) following VR interventions compared with controls [37].

The level of immersion further influences differences in effectiveness across VR systems. As summarized in Table 2, full- and semi-immersive VR systems generally demonstrate greater engagement and therapeutic impact than non-immersive approaches. However, they

also pose practical challenges related to usability, setup complexity, and potential discomfort in older populations [37].

Table 2. Comparative effectiveness of VR systems by immersion level.

Immersion Level	Typical Systems	Strengths	Limitations
Non-immersive VR	Desktop; tablet-based	Simple; accessible	Limited engagement; low realism
Semi-immersive VR	Large screens; projection systems	Moderately engaging	Usability challenges for older adults
Fully immersive VR	Head-mounted displays	High engagement; high realism	Complex setup; potential motion sickness

4.4. Emerging Opportunities for VR Interventions

Recent developments in VR applications for dementia care extend beyond individual, clinic-based interventions toward home-based protocols and caregiver-oriented approaches. These emerging models reflect a broader shift from patient-centered to relationship-centered care, recognizing the interconnected needs of individuals with dementia and their care partners.

Home-based VR protocols have demonstrated particular promise in increasing accessibility and continuity of care. The VRx@Home protocol, for example, illustrates the feasibility of delivering VR interventions directly within home environments, enabling shared engagement between persons with dementia and their caregivers [28]. By supporting dyadic participation, such approaches facilitate communication, emotional connection, and joint activity, which are often diminished as dementia progresses. Importantly, home-based delivery reduces logistical barriers associated with travel and clinical visits, making VR interventions more scalable and sustainable in real-world care settings.

In parallel, VR-based caregiver training programs have emerged as a complementary application domain. These programs use immersive, scenario-based simulations to expose caregivers to common dementia-related behaviors and caregiving challenges, thereby improving practical caregiving skills and fostering empathetic understanding [38], [39]. Through experiential learning, caregivers can better anticipate behavioral responses, practice supportive strategies, and develop confidence in managing complex care situations.

Beyond training, interactive VR experiences have also been shown to promote social engagement and emotional well-being for both patients and caregivers [28], [40]. By creating shared virtual experiences, VR interventions can strengthen relational bonds and mitigate social isolation, which is a significant concern for families affected by dementia. Collectively, these applications highlight the potential of VR to address not only symptom management but also the broader psychosocial dimensions of dementia care.

A summary of key VR application domains, techniques, targeted symptoms, and reported outcomes is provided in Table 3, illustrating the diversity of current VR-based approaches in dementia care.

Table 2. Summary of VR applications in dementia care.

Application Type	Key Techniques	Targeted Symptoms	Main Findings	Ref
Home-based VR	Multisensory environments; remote delivery protocols	Social engagement; quality of life	Improved emotional connection; feasible home-based implementation	[28]
VR music therapy	Adaptive music environments; EEG-based feedback	Anxiety; frustration; memory-related symptoms	Reduced frustration; enhanced cognitive and emotional outcomes	[29]
VR reminiscence therapy	Realistic and historical virtual environments	Anxiety; social disconnection	Increased engagement; reduced anxiety; high user satisfaction	[34]
VR cognitive training	Interactive tasks; motion and gesture tracking	Attention; working memory; mood	Improved mood; cognitive gains; good tolerability	[36]

5. Challenges and Limitations of Using VR

Although VR offers substantial potential in dementia care, its practical implementation is accompanied by a range of challenges that may limit accessibility, usability, and therapeutic effectiveness. The impact of VR interventions is shaped not only by technological factors but also by physical, cognitive, and emotional characteristics of older adults with dementia, as well as by their willingness and capacity to engage with unfamiliar digital systems. Design-related constraints, including interface complexity and sensory intensity, further influence the extent to which VR can be safely and effectively integrated into routine dementia care. This section outlines key challenges that must be addressed to support responsible and inclusive adoption of VR-based interventions.

5.1. Physical and Cognitive Barriers in Dementia Care

Older adults with dementia frequently experience physical and cognitive limitations that can hinder effective interaction with immersive VR systems. Age- and disease-related declines in motor coordination, strength, balance, and fine motor control may impair the ability to manipulate VR interfaces or perform gesture-based interactions. At the same time, cognitive impairments involving memory, attention, and executive function reduce the capacity to follow instructions, navigate virtual environments, and sustain task engagement, leading to increased errors and reduced efficiency during VR-based activities [40], [41].

These barriers are particularly relevant in immersive environments, where high levels of interactivity and sensory stimulation are central to therapeutic impact. While multisensory engagement is one of VR's primary advantages, excessive visual complexity, rapid motion, or dense auditory input may overwhelm individuals with moderate to advanced cognitive impairment, resulting in cognitive overload rather than therapeutic benefit [40], [41]. Consequently, VR systems intended for dementia care require careful adaptation, including simplified user interfaces, reduced visual clutter, clear and consistent audio cues, and gradual progression of task difficulty to align with users' cognitive and sensory capacities [24], [40], [41].

The diversity and co-occurrence of impairments that affect VR usability are illustrated in Figure 11. The figure highlights how sensory deficits (e.g., visual and hearing impairments), motor limitations (e.g., reduced coordination and balance), and cognitive decline frequently overlap in older adults. Importantly, many individuals with dementia experience multiple impairments simultaneously, compounding usability challenges and increasing the likelihood of disengagement or adverse experiences if systems are not appropriately designed [40]. These overlapping conditions underscore the need for holistic, adaptive VR design strategies that accommodate multiple functional limitations rather than addressing impairments in isolation.
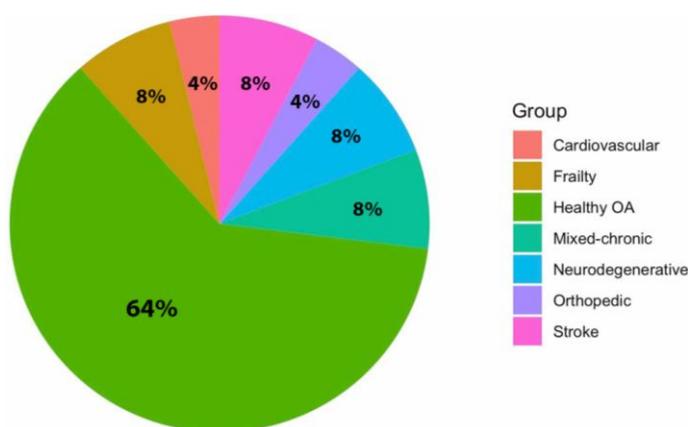

Figure 11. Distribution of clinical conditions affecting VR usability in older adults [40].

5.2. Technology Acceptance and Anxiety Among Dementia Patients

Technology acceptance and anxiety strongly influence the adoption of VR in dementia care among older adults. Limited technological experience and reduced self-efficacy can increase apprehension toward digital systems, potentially exacerbating behavioral and psychological symptoms of dementia (BPSD) rather than alleviating them [10], [40]. Studies indicate that older adults with limited exposure to digital technologies often prefer exploratory, low-

demand interactions, while complex interfaces and multi-step tasks can trigger frustration and disengagement [10], [40].

Technology-related anxiety in older populations arises from multiple sources, including fear of damaging equipment, concern about appearing incompetent, and unfamiliarity with interaction paradigms that are common among younger users [10], [42]. In the context of dementia care, these concerns are amplified by cognitive impairments that reduce confidence in learning new systems. Although VR has demonstrated the ability to reduce anxiety through familiar and emotionally meaningful environments—such as virtual reminiscence settings associated with reductions in STAI scores [34]—the initial introduction of VR hardware may itself provoke anxiety. Head-mounted displays, in particular, can temporarily increase distress by limiting visual contact with the physical environment and altering sensory perception, especially during early exposure [10], [42].

To address these challenges, tailored implementation strategies are required to improve acceptance and support emotional well-being. Gradual exposure protocols that begin with short, low-intensity or non-immersive VR experiences and progressively increase immersion and session duration have been shown to reduce initial anxiety and improve comfort [10], [42]. In addition, the presence of caregivers or clinical staff during VR sessions provides reassurance, assists with technical issues, and enhances perceived safety, thereby mitigating technology-related anxiety and promoting sustained engagement [42].

Conceptual frameworks for understanding technology acceptance among older adults are summarized in Figure 12. These include the Senior Citizens' Acceptance of Information Systems (SCAIS) model, the Technology Acceptance Model (TAM), the Transformation of Flow (ToF) framework, and user experience (UX)–oriented approaches. Together, these models emphasize perceived usefulness, ease of use, enjoyment, and social influence as central determinants of adoption. In dementia care, VR interventions must be perceived as genuinely beneficial rather than merely novel, require minimal learning effort, and be endorsed by trusted caregivers and clinicians to maximize acceptance and long-term use [10], [40].
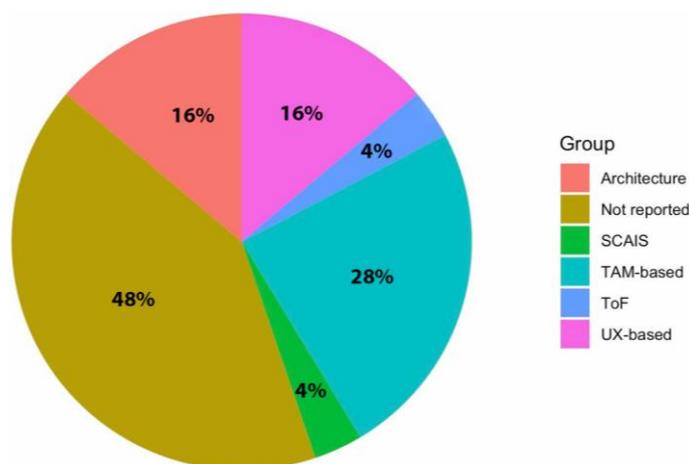

Figure 12. Conceptual models of technology acceptance and usability relevant to VR adoption among older adults [40].

5.3. Usability Challenges in Immersive VR for Dementia Interventions

Immersive VR systems, particularly head-mounted displays (HMDs), present distinct usability challenges for individuals with dementia when compared with non-immersive or semi-immersive alternatives. While immersive systems offer a heightened sense of presence, studies indicate that older adults with cognitive impairment often encounter difficulties when performing cognitively demanding tasks—such as memory or executive function exercises—within fully immersive environments [40]. Challenges in understanding task instructions, maintaining spatial orientation, and coping with motion-tracking inaccuracies can negatively affect both performance and the user experience [40].

Equipment-related factors further constrain usability in real-world care settings. The physical weight and fit of head-mounted displays, cable management, hygiene concerns associated with shared devices, and the need for repeated calibration introduce practical barriers that often require technical support, which is not readily available in dementia care

environments [24], [40]. These factors can increase setup time, reduce session efficiency, and limit the scalability of immersive VR interventions outside specialized research contexts.

User preference also plays an important role in determining usability. Evidence suggests that individuals with dementia do not consistently favor fully immersive systems and may prefer semi-immersive configurations, particularly for emotionally oriented interventions such as reminiscence therapy [12]. Semi-immersive systems preserve peripheral vision and awareness of the physical environment, reduce feelings of disorientation, and allow continued social interaction with caregivers or family members during use. In contrast, fully immersive head-mounted displays may induce discomfort or claustrophobic sensations in some users, especially during prolonged exposure [12], [24].

These observations highlight the importance of adaptive VR design strategies that align technological complexity with therapeutic goals and user capacities. Recommended design approaches include simplified and enlarged interface elements, voice-based or gesture-based navigation, automated adjustment of task difficulty based on real-time performance, and shorter session durations to reduce fatigue [24], [40], [41]. In addition, offering semi-immersive alternatives can balance engagement and usability, supporting therapeutic benefits while respecting the functional limitations common in dementia populations [40], [41].

The relationship between immersion level and therapeutic effectiveness is illustrated in Figure 13, which shows a spectrum of VR systems ranging from non-immersive desktop applications to fully immersive head-mounted displays. Although higher immersion theoretically enhances presence, the relationship between immersion and therapeutic benefit is not linear in dementia care. Semi-immersive systems may represent a practical "middle ground," offering sufficient engagement while maintaining tolerability and usability, though optimal immersion levels are likely to vary depending on individual capacity, intervention type, and clinical objectives [12], [40].
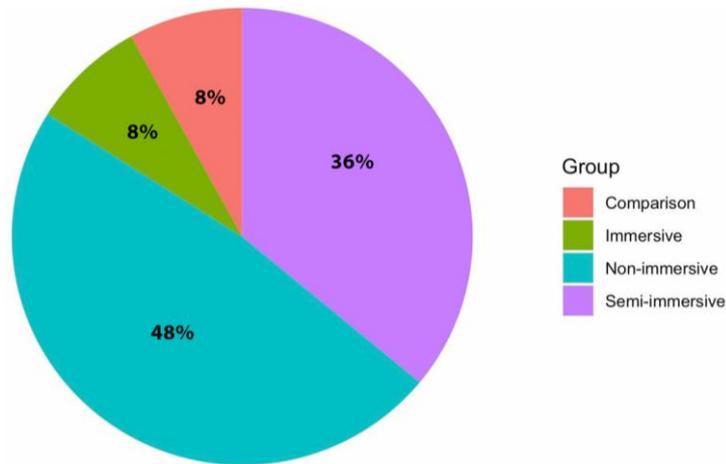

Figure 13. Levels of virtual immersion in VR systems used for dementia interventions [12], [40].

Common usability challenges and corresponding mitigation strategies are summarized in Table 4, highlighting the need for integrated solutions that address physical, cognitive, technological, and economic constraints simultaneously.

Table 4. Key challenges and potential solutions in VR implementation.

Challenge	Description	Potential Solution
Physical and cognitive barriers	Declines in motor skills; memory and attention impairments	Customized interfaces; shorter and simpler sessions
Technology acceptance	Low familiarity; apprehension toward digital systems	User-friendly design; gradual training and support
Usability constraints	Navigational complexity; limited realism or overload	Streamlined interaction; intuitive VR content

6. Cost-Effectiveness and Accessibility of VR Therapies

The integration of VR into dementia care raises critical questions regarding affordability, scalability, and long-term economic sustainability. Although VR technologies have become more accessible in recent years, substantial barriers remain related to initial investment, ongoing operational costs, and equitable access across healthcare systems and socioeconomic contexts. Clarifying the economic implications of VR interventions is therefore essential for guiding resource allocation decisions and ensuring that clinically effective technologies can be adopted at scale.

6.1. Hardware and Implementation Costs

The cost of VR hardware has decreased markedly over the past decade, with consumer-grade head-mounted displays now available at prices ranging from approximately USD 300 to 1,000 [38], [43]. However, total implementation costs extend well beyond hardware acquisition and include software licensing, content development or customization, technical infrastructure, and physical space requirements for safe use [43]. Clinical-grade VR systems designed specifically for healthcare settings—often incorporating enhanced hygiene features, simplified interfaces, and curated therapeutic content—typically remain substantially more expensive than consumer devices [43], [44].

Additional costs arise in clinical environments due to staff training, supervision during VR sessions, technical troubleshooting, and routine equipment maintenance [40], [43]. These expenditures can be particularly prohibitive in low- and middle-income countries, where healthcare budgets are constrained, and investment in emerging technologies competes with essential services [15], [44]. Moreover, the rapid pace of technological advancement raises concerns about equipment obsolescence, as VR hardware may need to be replaced every 3 to 5 years to remain compatible with evolving software and content ecosystems [43].

6.2. Operational and Human Resource Considerations

Beyond upfront costs, operational expenses represent a major determinant of VR feasibility. Many current VR interventions require trained personnel to assist patients, manage equipment, monitor safety, and respond to technical issues during sessions [40], [43]. This reliance on human supervision increases labor costs and limits scalability, particularly in care settings already experiencing workforce shortages [43], [45].

Emerging delivery models offer potential pathways to mitigate these constraints. Home-based protocols such as VRx@Home enable remote intervention delivery and may reduce the need for continuous professional supervision while maintaining therapeutic benefits [28]. Such approaches may also alleviate caregiver burden by supporting shared activities and reducing reliance on professional caregiving services [28], [45], [46]. As VR systems continue to evolve toward greater autonomy—incorporating features such as automated session logging, progress tracking, and adaptive difficulty adjustment—the demand for intensive staff involvement may decrease, improving overall cost-effectiveness [43], [45].

6.3. Potential Long-Term Cost Savings

Despite substantial upfront and operational investments, VR interventions may generate meaningful long-term economic benefits through several mechanisms. First, by reducing behavioral and psychological symptoms of dementia and supporting cognitive function, VR interventions may decrease reliance on pharmacological treatments and associated healthcare costs linked to adverse drug effects [4], [18]. Given the well-documented associations between antipsychotic use and increased hospitalizations, cerebrovascular events, and mortality in dementia populations [18], [21], even modest reductions in medication use could offset VR-related expenditures over time [47].

Second, VR interventions may help delay institutionalization by enhancing home-based care and supporting aging in place [28], [47]. Institutional care is among the largest cost drivers in dementia management, with annual expenses frequently exceeding USD 50,000–100,000 per individual in high-income countries [16], [47]. Even short delays in nursing home admission—measured in months rather than years—can translate into cost savings that surpass the costs of VR equipment and program implementation [47].

Third, VR-based caregiver training and support initiatives may reduce caregiver burden, burnout, and associated healthcare utilization [15], [28], [45]. Caregivers of individuals with

dementia experience elevated rates of depression, anxiety, and physical illness, leading to increased healthcare costs and productivity losses [15], [45]. Interventions that support caregiver well-being may therefore yield indirect economic benefits extending beyond patient-centered outcomes [45].

6.4. Evidence on Cost-Effectiveness

Despite these plausible pathways, empirical evidence on the cost-effectiveness of VR interventions in dementia care remains limited. Most published studies emphasize clinical outcomes rather than economic evaluation, and relatively few include formal cost-effectiveness or cost-utility analyses [43], [47]. A systematic review of VR applications for community-dwelling older adults reported promising effects on fall prevention, cognitive maintenance, and mental health, but highlighted the absence of robust economic evaluations that incorporate quality-adjusted life years (QALYs), caregiver outcomes, and broader societal costs [44], [47].

Preliminary analyses suggest potential economic viability under certain assumptions. One pilot economic evaluation indicated that VR interventions could be cost-effective relative to standard care if cognitive and functional benefits are sustained sufficiently to reduce healthcare utilization and delay institutionalization [47]. However, such analyses rely heavily on modeled assumptions rather than long-term empirical data [47]. Similarly, a feasibility study in long-term care facilities reported potential cost savings associated with reduced psychotropic medication use and decreased need for intensive behavioral management, although upfront costs remained substantial [16], [47].

6.5. Accessibility and Equity Considerations

Ensuring equitable access to VR-based dementia interventions requires addressing barriers beyond cost alone. Cultural adaptation of VR content is essential to ensure relevance, acceptability, and therapeutic effectiveness across diverse populations [9], [24], [28]. VR experiences developed primarily for Western contexts may not resonate with individuals from different cultural backgrounds, limiting engagement and benefit [9], [24]. Language differences, variable levels of technological literacy, and cultural attitudes toward technology further influence adoption [9], [10], [44].

Infrastructure requirements also constrain accessibility. Reliable internet connectivity for cloud-based systems, sufficient physical space for safe VR use, and access to technical support may be limited in under-resourced settings [15], [44]. Rural communities, low-income neighborhoods, and developing regions face particular challenges in meeting these prerequisites [44], [48].

Innovative delivery models may help mitigate these disparities. Lower-cost semi-immersive systems using tablets or projection technologies can deliver therapeutic benefits at a fraction of the cost of head-mounted displays [12], [24], [44]. Mobile VR clinics and community-based programs—implemented through partnerships with libraries, senior centers, and faith-based organizations—offer additional strategies for expanding access while sharing resources [44], [48]. Policy mechanisms, including public funding, insurance coverage, and cross-sector partnerships, will be critical to preventing VR technologies from exacerbating existing inequities in dementia care [44], [47], [48].

6.6. Future Directions for Economic Research

Future research should prioritize comprehensive health economic evaluations using standardized methodologies to enable comparison across interventions and healthcare systems. Cost-effectiveness analyses should incorporate multidimensional outcomes, including cognitive function, BPSD, quality of life, caregiver burden, healthcare utilization, and institutionalization rates [47]. Cost-utility analyses employing QALYs or disability-adjusted life years (DALYs) would further support comparisons with other healthcare interventions and inform policy decisions [47].

Comparative effectiveness studies examining VR relative to established non-pharmacological interventions—such as traditional reminiscence or music therapy—as well as pharmacological treatments are also needed [47]. In addition, research should explore optimal implementation strategies, including identification of patient subgroups most likely to benefit, ideal intervention duration and frequency, and the most cost-effective delivery models (e.g.,

individual versus group sessions, clinic-based versus home-based, supervised versus autonomous use) [43], [47]. Finally, longitudinal studies with extended follow-up periods are essential to validate assumptions regarding sustained clinical benefits and long-term cost savings, which remain largely speculative in the current literature [47], [49].

7. Discussion

7.1. Synthesis of Findings: Cross-Study Patterns and Analytical Insights

The body of evidence reviewed suggests that VR interventions can support cognitive stimulation, reduce certain behavioral and psychological symptoms of dementia (BPSD), and enhance emotional well-being across multiple therapeutic modalities. Rather than reiterating individual study outcomes, this section synthesizes cross-study patterns to clarify the mechanisms, trade-offs, and contextual factors that shape when and why VR interventions are effective, as well as the conditions under which their impact is limited.

7.1.1. Differential Effects Across Cognitive Domains: Mechanistic Explanations

Across studies, improvements in memory outcomes are more consistent than gains in attention or executive function. This pattern can be explained by VR's ability to engage relatively preserved implicit, emotional, and autobiographical memory systems in dementia, which are more resilient than higher-order executive processes [31], [37], [50]. Multisensory and context-rich environments activate autobiographical memory networks more effectively than abstract cognitive exercises, accounting for the stronger emotional and memory-related effects observed in reminiscence-oriented interventions [31], [34], [51].

In contrast, limited or inconsistent effects on visuospatial ability and gait appear to reflect design and implementation constraints rather than intrinsic limitations of VR technology. Passive or visually focused VR experiences may be insufficient to modify motor or spatial abilities without integration with physically embodied training protocols, such as treadmill-based or task-specific movement interventions [52], [53]. These domain-specific differences underscore that therapeutic efficacy depends on aligning VR modality and task demands with preserved cognitive capacities and targeted outcomes, rather than applying uniform VR protocols across heterogeneous patient populations [24], [31], [50].

7.1.2. BPSD Reduction: Why Reminiscence-Based VR Often Outperforms Cognitive Training

Reminiscence-based VR interventions consistently demonstrate stronger effects on BPSD than cognitively demanding training paradigms. This advantage likely arises from engagement of preserved autobiographical and emotional memory systems that support identity, emotional regulation, and a sense of continuity despite cognitive decline [31], [34], [51]. Familiar virtual environments provide safety cues and emotional grounding, reducing anxiety and agitation through mechanisms of familiarity and affective resonance [24], [34], [51].

By contrast, cognitive training approaches that emphasize sustained attention, working memory, and executive control may exceed the cognitive capacity of some individuals with dementia, particularly beyond early disease stages. When task demands surpass available cognitive resources, frustration and distress may emerge, potentially counteracting therapeutic goals [36], [41], [51]. These findings suggest that emotionally oriented interventions are generally more suitable for BPSD management, whereas cognitively demanding tasks may be more appropriate for individuals with MCI or early-stage dementia who retain sufficient cognitive reserve [6], [50]. Adaptive VR systems that dynamically adjust task difficulty based on performance or emotional state represent a promising intermediate strategy, offering cognitive stimulation while minimizing risks of under- or over-stimulation [13], [29], [50].

7.1.3. Immersion Level Trade-offs: Challenging the "More Is Better" Assumption

Although higher levels of immersion theoretically enhance presence, fully immersive VR does not consistently yield superior therapeutic outcomes compared with semi-immersive alternatives [12], [37]. Fully immersive systems introduce additional cognitive load through interface navigation and sensory enclosure, which may overwhelm individuals with cognitive impairment and divert attentional resources away from therapeutic engagement [12], [40], [41]. Concerns related to discomfort and cybersickness further constrain session duration and adherence in older populations [10], [11].

Semi-immersive systems mitigate several of these challenges by preserving peripheral awareness, reducing disorientation, and enabling social interaction during sessions. The ability for caregivers to remain physically present and engaged appears particularly relevant in dementia care, where relational context and reassurance influence emotional responses [24], [28], [39]. Practical considerations—including ease of setup, group usability, and cost-effectiveness—also favor semi-immersive approaches in many clinical and community settings [24], [43], [44].

Collectively, these patterns indicate that optimal immersion levels are context-dependent. Fully immersive systems may be suitable for selected individuals at early disease stages, whereas semi-immersive configurations often offer a more favorable balance between engagement, usability, and tolerability for moderate-to-severe dementia or for group-based interventions [6], [12], [24].

7.1.4. Engagement, Personalization, and Multisensory Stimulation as Core Mechanisms

A consistent cross-study observation is heightened engagement and motivation during VR interventions, reflecting the interactive and multisensory nature of immersive environments. This engagement likely mediates therapeutic effects through mechanisms aligned with cognitive stimulation and sensory integration theories, supporting improvements in emotional regulation, attentional focus, and social connectedness [30], [44].

Personalization emerges as a critical determinant of effectiveness. Evidence suggests that realism and personal relevance are more influential than graphical sophistication, with photorealistic and personally meaningful content eliciting stronger engagement than generic or stylized environments [34]. These findings emphasize that therapeutic impact may be maximized by incorporating individualized content—such as familiar locations, culturally relevant settings, or personal photographs—rather than prioritizing technological novelty alone [24], [34], [50].

Home-based and adaptive systems further extend this personalization by tailoring content to individual histories and preferences and, in some cases, dynamically adjusting it using biometric indicators of emotional or cognitive state [13], [28], [29], [50]. Importantly, interventions that include caregivers as active participants foster relational engagement and shared positive experiences, reinforcing a relationship-centered care model that addresses the broader psychosocial context of dementia [15], [28], [39], [46].

7.1.5. Conditions Under Which VR Effects Are Attenuated

Several factors appear to moderate or limit the effectiveness of VR interventions. Disease severity is a key determinant, with most evidence supporting benefits in individuals with MCI or mild-to-moderate dementia [6], [36], [37]. Evidence for advanced dementia remains sparse, likely reflecting reduced capacity for sustained engagement with interactive technology rather than definitive ineffectiveness [40], [41], [51]. Appropriately simplified VR experiences focused on sensory stimulation may hold promise for this population, but empirical validation remains limited [25], [51].

Technological literacy and prior exposure to digital devices further influence outcomes. Individuals with limited familiarity may require extended orientation and support, which can affect feasibility and scalability in certain settings [9], [10], [40], [42]. Cultural relevance also moderates acceptance and engagement, highlighting the importance of culturally adapted content and sensitivity to local attitudes toward technology and care practices [9], [15], [24].

Intervention design parameters—including session duration, frequency, personalization, and level of facilitator support—also shape outcomes. Short-term interventions often demonstrate immediate emotional effects, whereas sustained cognitive or functional benefits likely depend on repeated and longitudinal exposure [13], [49], [51]. The optimal intervention "dosage" remains unclear and is likely to vary across populations and therapeutic goals [49], [51].

7.1.6. Distinguishing Evidence Strength: RCTs Versus Pilot Studies

A central interpretive challenge is differentiating findings supported by robust randomized controlled trials and meta-analyses from those derived primarily from pilot or feasibility studies. Meta-analytic evidence provides moderate support for VR's efficacy in improving memory, attention, and overall cognition in MCI and dementia populations [6], [9], [13], [37], offering a relatively solid basis for careful clinical consideration.

By contrast, broader claims about reductions in medication use, delayed institutionalization, or sustained reductions in caregiver burden remain largely inferential. While supported by theoretical rationale and preliminary findings [4], [16], [28], [47], these outcomes have not been confirmed by large-scale, long-term trials and should be considered promising but unproven [51]. Similarly, emerging applications—including AI-driven personalization, home-based delivery models, and caregiver-focused interventions—demonstrate feasibility and acceptability but require stronger evidence of efficacy before widespread implementation can be recommended [13], [28], [29], [38], [39].

Maintaining this distinction is essential to avoid both premature adoptions based on overstated claims and undue dismissal of innovative approaches that warrant further investigation. A balanced interpretation acknowledges early signals while emphasizing the need for rigorous validation to guide evidence-based dementia care [51].

7.2. Well-Being and Quality of Life: Expanding the Therapeutic Focus

Although much of the VR literature in dementia care has prioritized cognitive and behavioral outcomes, quality of life and emotional well-being constitute equally important therapeutic dimensions that are often underrepresented in empirical evaluation. Quality of life in dementia is inherently multidimensional, encompassing emotional well-being, social engagement, autonomy, comfort, and opportunities for meaningful activity—dimensions that are only partially captured by conventional cognitive or symptom-based outcome measures [54].

Synthesized evidence suggests that VR may influence quality of life through mechanisms that extend beyond direct cognitive improvement. One pathway involves expanding access to meaningful experiences that are otherwise limited by mobility constraints, frailty, or institutionalization. By enabling virtual travel, participation in cultural events, or revisiting personally significant places, VR broadens experiential opportunities and supports autonomy and pleasure even as cognitive or functional decline progresses [22], [25], [54]. This experiential enrichment addresses aspects of well-being that are largely beyond the reach of pharmacological interventions.

A second pathway relates to emotional continuity and identity preservation. VR-based reminiscence and music interventions engage preserved autobiographical and emotional memory systems, fostering positive affect and reinforcing a sense of self over time [33], [34], [51], [54]. These emotionally oriented mechanisms target existential and psychological dimensions of dementia—such as meaning, dignity, and emotional security—that lie outside the scope of symptom-focused medical treatment [51], [54].

Social connection represents a third mechanism linking VR to well-being outcomes. When implemented in group contexts or with caregiver participation, VR facilitates shared experiences that promote interaction, conversation, and relational bonding [28], [39], [46]. Such shared engagement may counteract social withdrawal and loneliness, which are common but often underaddressed features of dementia [28], [39], [54]. For caregivers, participation in VR sessions can create positive shared moments that partially offset the stress and emotional burden of caregiving [28], [39].

Despite these promising mechanisms, empirical evidence on VR's impact on quality of life remains methodologically limited. Existing studies report improvements in mood, engagement, and subjective satisfaction following VR exposure [34], [36], [46], but few employ validated quality-of-life instruments or assess durability beyond short-term follow-up [54]. This gap underscores the need for future studies to integrate standardized patient- and proxy-reported quality-of-life measures, as well as observational tools that capture well-being in individuals with advanced cognitive impairment [49], [54].

Caregiver well-being also warrants more systematic attention. While theoretical and preliminary evidence suggest that VR may indirectly benefit caregivers by reducing BPSD, providing respite, or enhancing caregiving competence [15], [39], [45], caregiver outcomes are rarely included as primary endpoints. Given the substantial emotional, physical, and economic burden borne by caregivers, this omission represents a critical gap in the current literature [15], [45].

7.3. Future Care Models: Integration, Implementation, and Innovation

The notion of "future care models" for dementia extends beyond technological capability to encompass how VR interventions are integrated into routine practice, scaled across care

settings, and supported by policy, infrastructure, and innovation. Synthesizing existing evidence highlights both opportunities and structural challenges that will shape VR's role in dementia care moving forward.

7.3.1. Integration into Clinical Practice and Home-Based Care

For VR to transition from experimental intervention to routine care modality, it must be embedded within existing clinical workflows and care delivery systems. Evidence suggests that VR is best positioned as a complement to established non-pharmacological approaches—such as music therapy, reminiscence therapy, and occupational therapy—rather than as a standalone replacement [25], [33]. Early implementations in acute and long-term care settings demonstrate the feasibility of managing BPSD and enhancing engagement, but these remain context-dependent and resource-intensive [4], [16], [25].

Home-based care represents a particularly promising integration pathway. Protocols such as VRx@Home illustrate how VR can support aging in place, extend access beyond institutional settings, and reduce logistical burdens associated with clinic-based delivery [28]. As VR systems become more autonomous and user-friendly, home-based deployment may enable more frequent and sustained interventions with reduced professional supervision requirements [28], [43], [44].

However, successful integration depends on addressing practical implementation barriers. Staff training, clinician buy-in, and confidence in operating VR systems are essential for routine use [43], [45]. Workflow challenges—including scheduling, equipment sharing, documentation, and outcome tracking—must be resolved to prevent VR from becoming an additional burden rather than a supportive tool [43], [45]. Reliable technical support and maintenance infrastructure are similarly critical to ensure consistency and safety in real-world settings [43], [44].

7.3.2. Policy, Reimbursement, and Regulatory Considerations

Widespread adoption of VR interventions will ultimately depend on supportive policy and reimbursement frameworks. At present, most VR-based dementia interventions are funded through research or innovation grants rather than integrated into routine reimbursement mechanisms [47]. The absence of standardized billing codes and coverage criteria remains a major barrier to scalability [47], [48].

Regulatory considerations extend beyond reimbursement. Safety standards for medical VR devices, content governance to ensure therapeutic appropriateness, and protections for sensitive health data collected through VR platforms—including biometric and usage data—are essential [43], [48]. Ethical challenges related to informed consent, emotional vulnerability, and equitable access require explicit frameworks tailored to cognitively impaired populations [48], [54].

Policy initiatives that prioritize pragmatic trials, establish quality standards for VR design and implementation, and encourage public–private partnerships may accelerate responsible adoption while minimizing inequities in access [44], [47], [48].

7.3.3. Technological Innovations: AI, Biometrics, and Adaptive Systems

Technological innovation continues to expand the potential scope of VR-based dementia care. Integration of artificial intelligence with biometric monitoring enables adaptive systems that respond dynamically to users' emotional and cognitive states, adjusting content difficulty, pacing, or sensory intensity in real time [13], [29], [50]. Such personalization aligns with emerging precision-medicine paradigms and may enhance both efficacy and tolerability.

Machine learning approaches offer additional opportunities to optimize intervention design by identifying individual response patterns and tailoring session parameters accordingly [13], [50]. Voice-based interaction and natural language processing may further reduce interface barriers for individuals with motor impairment or low technological literacy [13], [48]. Beyond VR alone, extended reality (XR) approaches combining virtual and augmented reality could support context-aware prompting, memory cues, or guided daily activities, while social VR platforms may facilitate remote social connection and shared experiences [48], [55].

Importantly, technological advancement must remain grounded in user-centered design. Prior experiences with healthcare technologies demonstrate that technical sophistication alone does not guarantee clinical adoption or benefit [42], [48]. Meaningful progress requires continuous involvement of people with dementia, caregivers, and frontline clinicians

throughout design, testing, and implementation processes to ensure alignment with real-world needs, capacities, and values [24], [39], [48].

7.4. Implications for Clinical Practice

From a clinical perspective, the accumulated evidence suggests that VR can function as a supportive, non-pharmacological component within comprehensive dementia care, particularly for the management of behavioral and psychological symptoms. Rather than replacing existing therapies, VR is best understood as an adjunct that enhances established non-pharmacological approaches—such as music therapy, reminiscence therapy, and sensory stimulation—by increasing engagement and personalization [25], [33]. Its principal clinical value lies in offering engaging alternatives that may reduce reliance on pharmacological strategies while supporting positive patient–caregiver interactions [4], [16].

Effective clinical use, however, requires careful patient selection and implementation planning. Usability constraints, cognitive capacity, cultural relevance, and individual preferences substantially influence therapeutic benefit [9], [24], [38]. Clinicians must therefore align VR content and immersion level with patients' cognitive abilities and emotional tolerance, rather than adopting a uniform intervention model. Structured orientation sessions and gradual exposure protocols can further support acceptance and minimize distress during early use [49], [51].

The synthesis of current evidence highlights the need for practical clinical guidance. Evidence-based frameworks specifying indications, contraindications, and optimal intervention parameters—such as session duration, frequency, content type, and level of supervision—would facilitate informed decision-making [49], [51]. In parallel, training programs for healthcare professionals should extend beyond technical operation to include therapeutic integration, safety monitoring, and alignment with individualized care plans [43], [45].

7.5. Gaps in Current Research

Despite encouraging trends, several substantive gaps limit the interpretability and generalizability of current evidence. A central limitation is the predominance of short-term studies, which constrains understanding of whether observed benefits are transient or sustained over time [37], [49], [51]. Longitudinal evaluations extending beyond immediate post-intervention assessments are necessary to determine durability, cumulative effects, and potential habituation.

Geographic and cultural concentration represents a second major gap. Most studies have been conducted in high-income regions, limiting insight into effectiveness, feasibility, and acceptability in low- and middle-income contexts where dementia prevalence is rising most rapidly [8], [9], [15], [38]. Without culturally adapted content and evaluation in resource-constrained settings, the global relevance of current findings remains uncertain [9], [15], [44], [48].

A third gap concerns outcome scope. While cognitive and emotional measures are commonly reported, domains such as caregiver burden, social participation, quality of life, and functional independence are inconsistently assessed [28], [46], [54]. These outcomes are central to lived experience and care sustainability, yet remain peripheral in much of the existing literature.

Methodological inconsistency further complicates synthesis. Heterogeneous reporting of VR design features—including immersion level, personalization strategies, sensory intensity, and interaction modalities—limits reproducibility and comparative analysis [8], [24], [40]. Finally, although theoretical models of VR's mechanisms are well articulated [30], [31], [51], empirical investigations directly examining neural, physiological, or process-level mechanisms remain scarce.

Safety reporting constitutes an additional gap. Although adverse effects are generally described as minimal, systematic monitoring and transparent reporting—particularly for non-serious but clinically relevant effects—are not uniformly implemented [10], [11], [51].

7.6. Future Research Directions

Future research should prioritize rigor, duration, and comparability. Well-powered, long-term randomized controlled trials are needed to establish sustained efficacy and to identify which patient profiles benefit most from specific VR modalities, levels of immersion, and personalization strategies [13], [49], [51]. Comparative effectiveness studies across non-

immersive, semi-immersive, and fully immersive systems are particularly important for resolving ongoing uncertainty regarding optimal intervention design [12], [24], [51].

Expanding research across cultural and socioeconomic contexts is equally critical. Cross-cultural validation and adaptation will be essential to ensure that VR interventions remain relevant and effective across diverse populations, particularly in regions facing rapidly increasing dementia prevalence [8], [9], [15], [28], [44]. Inclusive recruitment strategies and context-sensitive implementation models should accompany such efforts.

Technological innovation offers promising avenues but must be evaluated cautiously. AI-driven personalization and biometric integration may enhance engagement and responsiveness, yet require validation beyond feasibility to demonstrate meaningful clinical benefit [13], [29], [50], [51]. At the same time, future studies should broaden outcome assessment to include caregiver well-being, social engagement, quality of life, and economic impact, thereby capturing the full value proposition of VR-based dementia care [28], [45], [46], [54]. Finally, transparent reporting of null or negative findings and systematic economic evaluations are essential to avoid publication bias and support evidence-based decision-making [43], [47], [51]. Table 5 summarizes priority areas for future research and their intended contributions.

Table 5. Priority areas for future research in VR-based dementia care.

Research Focus	Rationale / Goal	Suggested Action
Long-term RCTs	Establish sustained efficacy and benefit profiles	Multi-year, multi-site randomized trials
Cross-cultural adaptation	Improve global relevance and equity	Culturally adapted content; inclusive trials
AI-driven personalization	Enable real-time adaptive interventions	Integration of EEG and heart-rate feedback
Broader outcome assessment	Capture caregiver burden, social engagement, QoL	Expansion of outcome measures

7.7. Limitations of the Review

This review is subject to several limitations. First, much of the available evidence is derived from pilot or feasibility studies with small samples and limited follow-up, restricting generalizability and confidence in long-term effects [8], [34], [36], [37], [49]. Second, the geographic concentration of studies in high-income regions limits insight into applicability across diverse cultural and resource settings [8], [9], [15], [38].

Heterogeneity in intervention design and outcome measurement further complicates synthesis. Variability in VR hardware, software, therapeutic focus, and evaluation metrics reduces comparability across studies and limits replication [8], [24], [40]. In addition, economic evidence remains underdeveloped; although VR is frequently proposed as a cost-saving intervention, robust cost-effectiveness data are sparse [25], [47]. Collectively, reliance on published literature introduces the possibility of publication bias, as positive findings are more likely to be reported than null or negative results [17], [51]. This bias may overstate perceived effectiveness, underscoring the importance of cautious interpretation.

8. Conclusions

This narrative review synthesizes current evidence indicating that VR constitutes a promising non-pharmacological adjunct in dementia care, with the most consistent benefits observed in memory-related outcomes and anxiety reduction, particularly through emotionally oriented and reminiscence-based interventions. Across studies, therapeutic effectiveness appears to depend less on technological sophistication and more on alignment between intervention design and preserved cognitive–emotional capacities, with semi-immersive systems frequently offering a pragmatic balance between engagement, usability, and tolerability.

A second core insight is that VR's therapeutic value extends beyond cognition to encompass emotional well-being, social connection, and relational engagement, especially when interventions are personalized and involve caregivers. These dimensions are central to quality of life in dementia yet remain underrepresented in outcome evaluation, highlighting a disconnect between measured endpoints and lived experience. Third, the evidence challenges the assumption that greater immersion uniformly produces better outcomes. Instead,

effectiveness is moderated by disease stage, user capacity, and context of use, underscoring the need for tailored rather than uniform implementation strategies. Collectively, these patterns position VR as a flexible therapeutic medium whose impact is contingent on thoughtful design and delivery rather than immersion alone.

Looking forward, translation into routine practice will require rigorous long-term trials, standardized reporting, and robust economic evaluation to clarify sustainability and cost-effectiveness. Clinical integration depends on clear patient-selection frameworks, workforce training, and reimbursement pathways, alongside user-centered design that prioritizes accessibility and cultural relevance. Advances in adaptive and home-based VR systems offer opportunities to extend care beyond clinical settings, but realizing this potential will require coordinated efforts to ensure equitable access and evidence-based implementation.

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