Title: **Augmented Reality (AR), Virtual Reality (VR), and Assistive Technologies in Dementia Care: Evidence, Applications, and Challenges**

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Key highlights:

- Major neurocognitive disorders or dementias are marked by decline in memory, language, visuospatial abilities, and executive function, leading to loss of independence, impaired daily living, and high caregiver burden.
- AR and VR offer immersive or context-aware environments that support cognitive stimulation, emotional well-being, spatial navigation, and behavioral symptom management through personalized, non-pharmacological interventions.
- Serious games, VR-exergames, AR overlays, object-detection systems, and wearable-integrated tools can assist with activities of daily living, provide real-time guidance, enhance safety, monitor mobility and fall risk, and deliver hands-free cognitive and functional support.
- Limited dementia-specific datasets, hardware constraints, small or heterogeneous clinical studies, and significant ethical and privacy concerns, especially around continuous monitoring, remain major barriers to large-scale adoption.

[Word Count: 999]

1. Introduction

Major neurocognitive disorders or dementias are characterized by decline across multiple cognitive domains, including memory, language, visuospatial abilities and executive function, ultimately leading to loss of independence and increasing reliance on caregivers. The most common subtype is Alzheimer's disease, with global prevalence rates currently exceeding 55 million individuals. This rate is projected to nearly triple by 2050, driven by population ageing and increased longevity [1]. These impairments profoundly disrupt activities of daily living, social participation, emotional well-being, and overall quality of life, while imposing substantial emotional, economic, and physical strain on caregivers [1]. Among the most disabling features of dementia are deficits in spatial navigation and orientation such as the abilities that support forming mental maps, interpreting cues, recalling routes, and safely interacting with the environment [2]. As these processes deteriorate, individuals become vulnerable to getting lost, falling, misusing appliances, or requiring constant supervision. These challenges have stimulated interest in emerging technologies, including augmented reality (AR), virtual reality (VR), illustrated in figure 1, object detection, and wearables, which aim to support autonomy, enhance safety, and deliver patient-centered non-pharmacological interventions tailored to cognitive decline.

2. Evidence for AR, VR, Gaming, and Object Detection in Dementia

Preliminary evidence shows that immersive VR and interactive *Serious Games for Dementia Care (SGDC)* can promote cognitive stimulation, physical training, engagement, and emotional well-being across ageing and dementia populations. Serious games developed for cognitive training have been shown to improve memory, attention, and executive functions [3]. As for VR-based exercises (VR-Exergames), several pilot and feasibility studies have demonstrated improvements in motivation, visuospatial skills, dual-task performance, and balance [4]. Systematic reviews also highlight moderate cognitive improvements and substantial reductions in depressive symptoms among older adults engaging in VR-Exergames [4]. In terms of behavioral and psychological symptoms of dementia (BPSD), immersive VR experiences depicting natural scenes, familiar neighborhoods, or culturally meaningful environments have been associated with improved mood, reduced agitation, and greater engagement [5].

Complementing immersive VR, AR-based technologies enable context-aware support in real-world environments. AR overlays can provide step-by-step prompts for instrumental Activities of Daily Living (ADLs), assist with locating essential objects, or guide way-finding both indoors and outdoors [6]. Object detection systems enhance this capability by identifying and localizing items in real time, supporting daily routines, compensating for memory lapses, and enabling reminders for medication, household tasks, as well as navigation. When combined with AR, object detection can trigger interactive cues such as text, audio, or visual, that guide users through complex activities [6, 7]. Recent systems, such as smartphone-optimized Convolutional Neural Networks (CNN) architectures and HoloLens-based TinyYOLO models, both designed to optimize object detection on resource-limited or smaller devices, have demonstrated increasingly fast inference times (<200 ms), multimodal cueing, and integration with conversational artificial intelligence to deliver personalized assistance [8, 9]. Smart-glasses prototypes leveraging YOLOv8 with cloud-based memory aids further illustrate the potential for portable, hands-free cognitive support in dementia care [9].

Finaly, wearables enrich these technologies by monitoring gait, sleep, wandering patterns, and risk behaviors, creating opportunities for early detection of functional decline and continuous caregiver-friendly oversight [10]. Together, these systems have the potential not only to provide cognitive training, physical stimulation, and assistance with object detection and daily activities, but also to enable continuous monitoring and assessment of

cognitive status, mobility and fall risk, and overall functional ability. This can ultimately support context-based cognitive assistance, promote autonomy, and improve quality of life.

3. Limitations, Technical Constraints, Ethical Challenges, and AR vs VR Considerations

Despite promising findings, current AR/VR wearables technologies face important limitations. Many object-recognition models are trained on general-purpose datasets lacking dementia-specific categories such as pillboxes, mobility aids, adaptive utensils, or medical devices, reducing ecological validity [8]. Lightweight or smartphone-based wearable architectures often struggle with small-object detection, cluttered home environments, or variable lighting, while systems deployed through more advanced smart glasses models remain constrained by battery, compute capacity, and hardware bulkiness [6, 9]. Validation studies are limited, with most research conducted on healthy or younger adults rather than individuals with dementia, leading to uncertain generalizability [3, 11]. VR studies frequently suffer from small sample sizes, limited follow-up duration, and heterogeneous protocols, complicating meta-analytic synthesis [4].

Ethical and privacy concerns pose additional challenges, especially for AR systems that rely on real-time video, audio, location data, and continuous environmental mapping [12]. Individuals with dementia often have diminished capacity to understand or consent to pervasive monitoring, raising risks of surveillance, stigma, or misuse of sensitive behavioral data [13]. Considerations around usability, digital literacy, data governance, and equitable access remain essential for the safe integration of AR/VR into dementia care.

Importantly, AR and VR differ in tolerability, immersion, and clinical applicability. AR is generally better tolerated by older adults because it maintains grounding in the physical environment, reducing sensory disconnect and minimizing cybersickness [14]. AR excels in real-world cueing, highlighting hazards, labeling objects, prompting ADLs, facilitating communication, and supporting navigation, making it particularly beneficial for mild-stage cognitive impairment or early dementia. VR, while more immersive and capable of simulating whole environments for motor or cognitive rehabilitation, may pose barriers due to headset bulk, motion sickness, and disorientation. Both modalities carry potential for reducing social isolation through mediated interactions, though cost, accessibility and user-centered design remain critical determinants of effectiveness.

4. Summary and Future Directions

AR, VR, object detection, and wearable-integrated assistive technologies represent a rapidly evolving and increasingly promising set of tools aimed at improving autonomy, safety, engagement, and quality of life for individuals living with dementia. Evidence from randomized trials, systematic reviews, and feasibility studies demonstrates meaningful benefits for cognition, mood, spatial navigation, behavioral symptoms, and ADL support, while advancements in computer vision and smart-device integration expand possibilities for real-time environmental assistance. However, limitations in dataset relevance, hardware scalability, clinical validation, privacy protections, and long-term outcome data necessitate further research. Future efforts should prioritize dementia-specific datasets, larger multi-site trials, ethical-first design, caregivers' involvement, and rigorous implementation studies in real-world settings. With thoughtful development, these technologies could transition from experimental prototypes to clinically integrated, person-centered tools that meaningfully support independence and reduce caregiver burden across the dementia trajectory.

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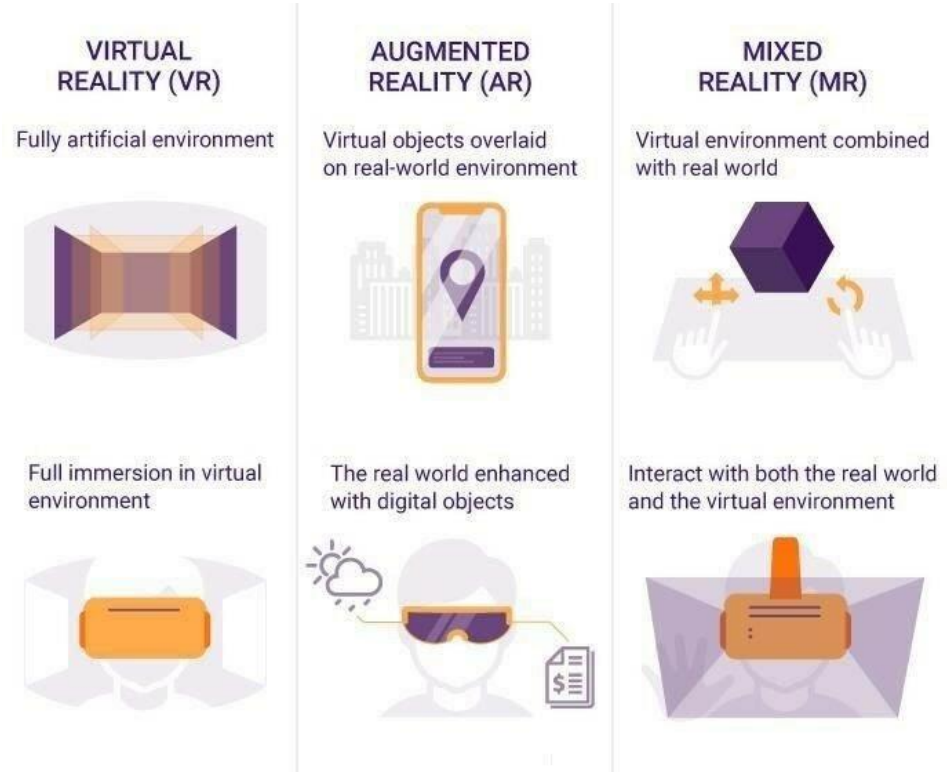

Figure 1. Concepts of VR, AR and their combination

(adapted from Imam, Mustafa and Imam, Mustafa, Changing the Paradigm of Mixed Reality (MR) in Education Sector through Microsoft HoloLens (September 10, 2020). International Journal of Scientific & Engineering Research, Volume 11, Issue 12, December-2020).