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# Virtual Reality for the assessment and treatment of cognitive impairment in the elderly: A scoping review

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## Abstract

*The review aims to analyze the recent scientific literature on Virtual Reality (VR) applied to elderly people with cognitive impairment or dementia.*
*One hundred and four articles were examined, concerning both the effectiveness of VR interventions, at different levels of immersion or with augmented reality, and the usability and acceptability of these technologies.*
*The use of VR for the diagnostic assessment of mental deterioration is also discussed.*
*Finally, the need for training to enhance the potential of VR in rehabilitation is underlined.*

*Keywords:* Virtual Reality; Elderly; Cognitive impairment; Dementia.

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# 1. Introduction

Can Virtual Reality (VR) be an effective intervention for people with cognitive impairment? This hypothesis needs to be verified in patients affected by dementia, a neurodegenerative disease that presents a series of cognitive issues, including memory, reasoning, language and attention problems, and that hinders normal daily activities, reducing the quality of life of patients and their caregivers. Moreover, VR, as an effective intervention, should be tested also in individuals with Mild Cognitive Impairment (MCI), a condition of deterioration that does not reach the levels of dementia but is a potential precursor of it.

VR offers a simulated environment that can help stimulate cognitive and motor functions, increasing skills and well-being (Riva & Gaggioli, 2019); it can engage people with impairment in new and meaningful ways. Today there is a continuous growth of research on VR as a tool for the diagnosis and intervention in dementia (Sobral & Pestana, 2020). However, further long-term studies are needed to validate its use in the therapeutic field and in the management of behavioral symptoms implied by cognitive impairment (Cibeira, Lorenzo-López, Maseda, López-López, Moreno-Peral, & Millán-Calenti, 2020).

The review presented intends to summarize the recent developments in empirical research on the subject.

# 2. Methods

## *2.1. Search strategy*

The study adopted a consolidated review methodology, following the PRISMA guidelines (Page, McKenzie, Bossuyt, Boutron, Hoffmann, Mulrow *et al.*, 2021). The articles included in the review were identified through the keywords “Virtual Reality and Cognitive Impairment” and/or “Dementia”, and/or “Alzheimer”, and/or “Augmented Reality and Dementia”, and were searched in the electronic databases Scopus, PubMed, WebOfScience, ScienceDirect, GoogleScholar, and ResearchGate, for the period from 2015 to 2023.

Two independent reviewers (M.C., R.S.) extracted data, selected articles by title/abstract and full-text, removed duplicates, and screened reference citations of eligible articles and related published systematic reviews on the topic. In case of disagreements in the passages listed above, these were resolved by the third author (S.D.) who supervised the whole process.

### *2.2. Eligibility criteria and data extraction*

We included reviews, meta-analyses, and experimental studies that met the following eligibility criteria: articles (1) published on or after 2015; (2) having as a study population people with dementia or Mild Cognitive Impairment, and (3) focused on the use of interventions based on VR programs. We excluded: (1) duplicates - i.e., similar articles by the same Authors; (2) irrelevant topics - e.g. other forms of cognitive impairment, deficits following stroke or psychiatric conditions, and (3) articles in which definitive results were not available.

The initial screening included 700 articles; excluding those not corresponding to the eligibility criteria, 104 articles (59 reviews, 45 studies) were selected to construct the scoping review database.

The flow diagram showing the summary of the process of selection is reported in Figure 1.

## 3. Results and discussion

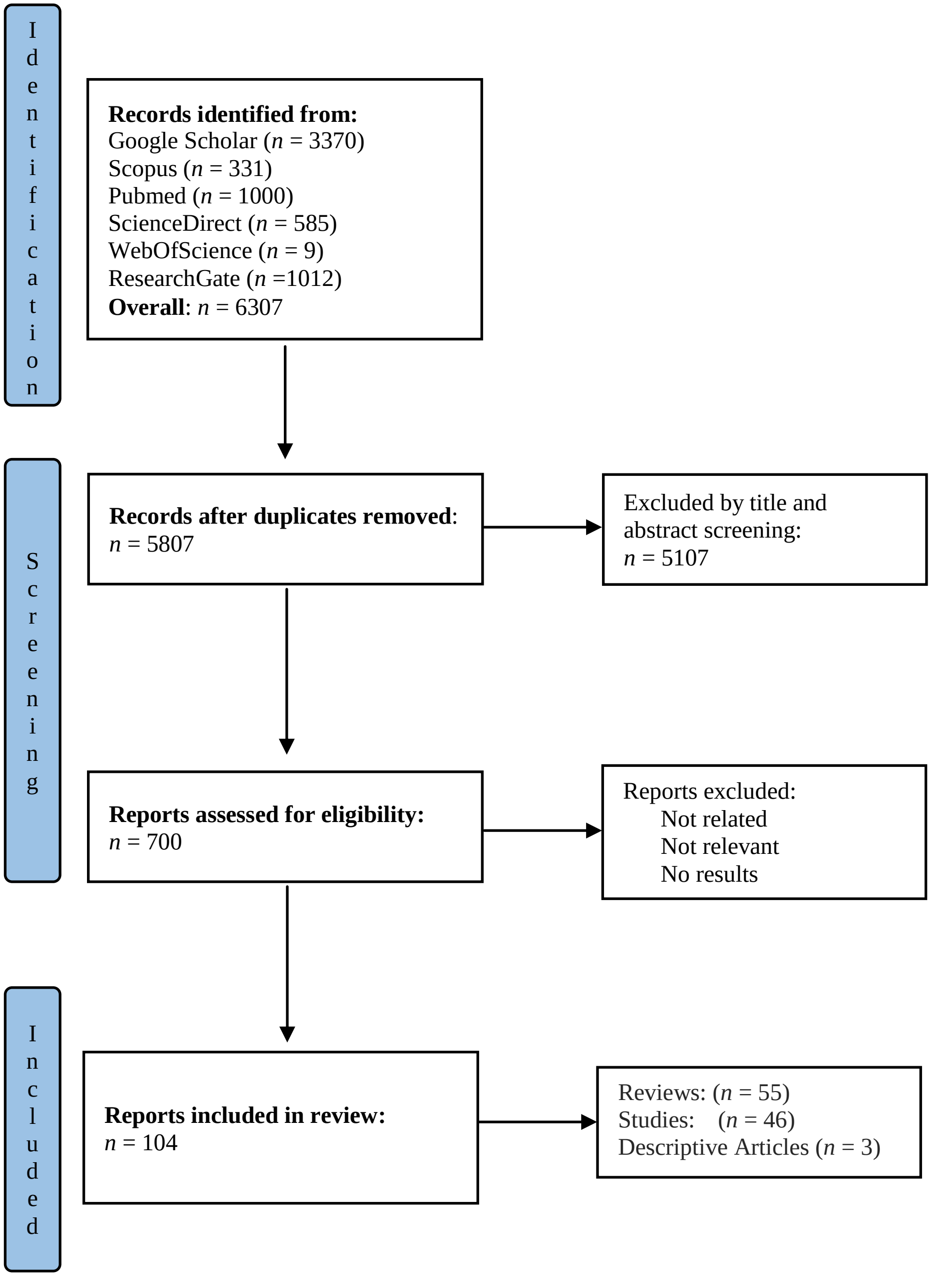
### *3.1. Usability and acceptability of VR as a premise of effectiveness*

Although most of the research carried out has investigated the effectiveness of VR treatment on people with cognitive impairment, the salient elements, to be preliminarily evaluated, are the usability and acceptability of the devices by these people, exploring the limits and benefits of the innovative technologies based on VR.

The usability of VR intervention techniques has been recognized in patients with cognitive decline, who did not report anxiety in approaching technological devices or problems of practical use (Andringa, Nuijten, Macville, Mertens, Kaptein, Bauer *et al.*, 2019). The review by Tuena and colleagues (Tuena, Pedroli, Trimarchi, Gallucci, Chiappini, Goulene *et al.*, 2020) tested the usability of VR applications in the elderly with and without cognitive impairment.

In line with these results, recent studies have highlighted the usability of VR as a group therapy intervention tool for the reduction of Behavior and Psychological Symptoms of Dementia (BPSD, Brimelow, Thangavelu, Beattie, & Dissanayaka, 2022).

Figure 1 – *Flow diagram reporting the criteria and the process of recruitment and screening of the articles analyzed for the review*



Gruber and collaborators (Gruber, Weigel, Tischendorf, Schaal, & Hellbach, 2022) conducted a pilot study aimed at analyzing the effects of the usability of a VR system on the mental state of elderly residents in nursing homes as well as the perception of the users (patients and nurses). The authors highlighted that the system had a positive effect on their state of mind and a positive openness to the use of these technological tools. Another relevant research was aimed at evaluating the usability of a VR mode of training in spatial navigation, using glasses and a joypad for movements. The first version of this system was applied to a target population (MCI) despite the users had no experience and practice in the technologies; the limitations found concerned visual technical aspects, but overall VR was judged positively (Tuena, Serino, Maestri, Pedroli, Stramba-Badiale, Brizzi *et al.*, 2022).

Qiu and colleagues (Qiu, Gu, Xie, Wang, Sheng, Zhu *et al.*, 2022) aimed to investigate the acceptance and tolerance of a VR cognitive training program in elderly Chinese adults, demonstrating that it was well tolerated without major or serious adverse events.

Vellani and collaborators (Vellani, Puts, Iaboni, & McGilton, 2022) also demonstrated the acceptability of the VYV (Voice Your Values) program, both by people with dementia and by their caregivers.

By studying the benefits of virtual shopping training courses to improve executive functions and instrumental activities of daily living in patients with MCI, the feasibility and effectiveness of the “Chinese virtual supermarket” system was also demonstrated, revealing significant acceptability in people with both MCI and dementia (Park, 2022; Zhu, Zhang, He, Huang, Lin, & Li, 2022).

An overall improvement emerged in some cognitive domains, such as executive and visual-spatial, attentive and linguistic skills, attributable specifically to the use of virtual reality from the analysis of reviews aimed at specifically investigating the effects of VR on general cognitive functioning in individuals with neurocognitive disorders. Furthermore, virtual reality can be used to enhance the effects of conventional therapies, promoting training with longer-lasting effects and a reduction in overall hospitalizations. Overall, this type of intervention promotes an increase in motivation and participation (Díaz Pérez & Flórez Lozano, 2018; Maggio, Maresca, De Luca, Stagnitti, Porcari, Ferrera *et al.*, 2019; Moreno, Wall, Thangavelu, Craven, Ward, & Dissanayaka, 2019; Jahn, Skovbye, Obenhausen, Jespersen, & Miskowiak, 2021). Other authors found no statistically significant effects on immediate memory, delayed memory, and instrumental activities of daily living (Zhong, Chen, Feng, Song, Huang, Liu *et al.*, 2021).

A further review (Papaioannou, Voinescu, Petrini, & Stanton Fraser, 2022) still investigating the role of VR in cognitive stimulation, found different results between patients with MCI and patients with dementia. In the former, moderate to high effects were found both on global cognition and specifically on the domains of attention, memory, and motor performance; in people with dementia, the same effects were observed on global cognition and on specific domains, such as memory and executive function. Finally, the review confirmed that the level of immersion and the type of training in people with MCI significantly influenced global cognitive functioning.

Arlati and colleagues (Arlati, Di Santo, Franchini, Mondellini, Filiputti, Luchi *et al.*, 2021) ascertained the good acceptability and usability of *immersive VR* (iVR) in patients with cognitive decline; we will consider this specific level of VR in a next paragraph.

### *3.2. Well-being and quality of life*

The effectiveness of VR systems in promoting the well-being and quality of life can also be said to be confirmed, as well as its acceptability by people with mild to advanced cognitive decline (Bacanoiu & Danoiu, 2022).

In the study by Park and collaborators (Park, Choi, & Kim, 2022) the proposed VR intervention program was shown to have a positive effect on the reduction of apathy and on the improvement of the quality of life of patients with dementia or MCI residing in nursing facilities.

Afifi and colleagues (Afifi, Collins, Rand, Otmar, Mazur, Dunbar *et al.*, 2022) reported an improvement in the patients' quality of life in general, specifically in terms of reduction of stress and in having better relationships with their family members. Positive effects of VR were also reflected in the family members, who showed a reduction in depressive symptoms and negative feelings; at the same time, their quality of life, in terms of mental health, also appeared to have improved. Furthermore, it was possible to identify the environments in which the patients themselves preferred experiencing VR interventions to minimize symptoms and thus improve their quality of life (Matsangidou, Frangoudes, Solomou, Papayianni, & Pattichis, 2022).

Walden and Feliciano (2022) found the reduction of agitation behaviors in people with dementia using VR intervention. Matsangidou and collaborators (Matsangidou, Solomou, Frangoudes, Ioannou, Theofanous, Papayianni *et al.*, 2023) confirmed that virtual reality can positively improve mental health, by enhancing emotional regulation. Furthermore, it emerged that increasing awareness of the role of VR in the stimulation, regulation and expression of emotions improves the understanding of the use of virtual reality by older adults with different forms of cognitive impairment.

In addition, natural landscapes, visualized through virtual reality, positively influenced the emotions of the elderly, as a stand-alone intervention or combined with traditional therapies, as was highlighted by the wide range of VR applications used in nursing homes and in communities for the elderly (Liu, Liu, Fernandez, Zou, & Lin, 2023) Further evidence of the benefits of "virtual nature" was reported by Spano and colleagues (Spano, Theodorou, Reese, Carrus, Sanesi, & Panno, 2023) who, through a systematic review, examined the effects of VR on psychological and psychophysiological outcomes, addressing three main themes: mood, stress, and restorativeness. A positive effect of the "virtual nature" was reported, although further verification is needed to generalize this result.

VR has been shown to be suitable in studying the interaction between emotion and cognition due to the ability to stimulate complex emotions. By systematically reviewing the studies investigating the relationship between memory and emotions, using immersive technologies, Mancuso and collaborators (Mancuso, Bruni, Stramba-Badiale, Riva, Cipresso, & Pedroli, 2023) contributed to improve the knowledge of how virtual reality works as an affective medium and of how the emotions arouse influence memory.

### *3.3. Dual-task VR*

Virtual reality-based interventions are a safe and effective approach to improve physical activities in older long-term care residents, but the evidence on physical performance still lacks stable evidence (Li, Li, & Chen, 2022).

VR has been included in physical and cognitive dual-task rehabilitation interventions to enhance balance, gait and to decrease the risk of falling, and also for executive functions of people with MCI and dementia, evaluating specific effects (Liao, Chen, Lin, Chen, & Hsu, 2019).

Imaoka and colleagues (Imaoka, Flury, Hauri, & de Bruin, 2022b) aimed at investigating the effects of visual stimuli via a head-mounted display device based on virtual reality (HMD-VR) on the posture in the elderly, reporting a correlation between stimulated body sway behaviors and cognitive performance.

Other studies also focused on the effectiveness of dual-task interventions. More specifically, Gambella and colleagues (Gambella, Margaritini, Benaducci, Rossi, D'Ascoli, Riccardi *et al.*, 2022) investigated the functionality of the *jDome® BikeAround* system, by integrating the *SocialBike* dual-task training program in which users were asked to pedal on a stationary bicycle recognizing target objects or animals that appeared along the way. The project was tested in the context of 'smart houses' with a VR-based application aimed at supporting frail elderly people in their homes.

Specific cognitive and motor rehabilitation interventions, such as “orientation therapy” and “Therapeutic Gardens”, were used through the VR platform, detecting positive effects on cognitive functions, in the former, and beneficial effects regarding stress reduction, pain management and improvement of cognitive abilities, in the latter (Chiu, Chen, Chen, & Huang, 2018; Uwajeh, Iyendo, & Polay, 2019). Thanks to dual-task interventions a significant reduction in the risk of falls was reported; moreover, a considerable improvement in the potential for cognitive-motor interference was also pointed out (Wajda, Mirelman, Hausdorff, & Sosnoff, 2017; Montero-Odasso & Speechley, 2018; Zhu, Sui, Shen, Zhu, Ali, Guo *et al.*, 2021).

The meta-analysis conducted by Yan and collaborators (Yan, Zhao, Meng, Wang, Ding, Liu *et al.*, 2022) highlighted how VR improved the global cognitive abilities in the elderly with MCI by combining cognitive and physical interventions; the parallel (dual-task) training was shown to have a greater effectiveness compared to the serial training of the skills.

Tuena and colleagues (Tuena, Borghesi, Bruni, Cavedoni, Maestri, Riva *et al.*, 2023), finally, described the *Cognitive Motor Dual-Task* (CMDT) rehabilitation procedures, evaluating their conditions and effectiveness. The results showed that CMDT training was pleasant, safe and effective; moreover, the positive effects obtained were maintained at a middle-term follow-up.

### *3.4. VR associated with other interventions*

The peculiar characteristics of VR (flexibility, personalization and acceptability) allow the development of a truly effective intervention with elderly people suffering from various mental and neurocognitive disorders

(Preston & Padala, 2022). These features allow the integration of VR with other interventions.

Some studies were focused on analyzing the effects of the interventions based on the use of Information and Communication Technology (ICT); these studies demonstrated positive effects on the improvement of cognitive functioning for older adults with MCI and confirmed that interventions integrated with virtual reality were more effective than other devices. Moreover, ICTs have shown to be promising in the treatment of anxiety and mood disorders, especially in people with MCI (Jung, Kim, & Park, 2021; Domenicucci, Ferrandes, Sarlo, Borella, & Belacchi, 2022).

Even “reminiscence therapy” has been associated with VR, confirming the usability and effectiveness of this modality, but underlining the need to pay attention to sensory technologies: e.g., the use of virtual sensory experiences, such as “the virtual smell”, is effective in VR reminiscence therapy in people with dementia (D'Cunha, Nguyen, Naumovski, McKune, Kellett, Georgousopoulou *et al.*, 2019; Appel, Ali, Narag, Mozeson, Pasat, Orchanian-Cheff *et al.*, 2021). It was also perceived as pleasant and safe to use, underlining its potential to stimulate communication skills and to foster reminiscence; however, no significant changes were observed in behavioral, psychological, or quality of life indicators (Reisinho, Raposo, & Zagalo, 2022).

Two articles (Fuchs, 2022; Huang & Yang, 2022) highlighted how the integration of virtual reality increased the potential of traditional reminiscence therapy, making it more engaging and impactful. Reminiscence with immersive VR was found to improve mood, reducing depressive symptoms, while no significant effects were reported on cognitive functions, global status and caregiver load immediately after the VR intervention. A study in detail compared two web app tools based on VR, i.e. the *Web-based reminiscence therapy* (WBRT) and the *Non-Immersive Reminiscence Therapy* (NIRT). A good overall usability and the potential to promote continuity of the experience were found for both, highlighting the use of these tools in the assistance of people with dementia and their families (Sun, Akhter, Uribe-Quevedo, Presas, Liscano, & Horsburgh, 2022).

VR was also tested within *Computerized Cognitive Training* (CCT), demonstrating a moderate effect at the cognitive level with MCI patients, and significant outcomes with AD people, by improving episodic memory. An increase in adherence to short-term and long-term drug treatment as well as a reduction in caregiver burden were also reported (Hill, Mowszowski, Naismith, Chadwick, Valenzuela, & Lampit, 2017; Moye, 2019).

The *Cognitive Remediation* (CR) program implemented by VR was also tested to verify its effectiveness, and the results report improvements in all cognitive domains (Perra, Riccardo, De Lorenzo, De Marco, Di Natale, Kurotschka *et al.*, 2023).

In the systematic review by Zuschnegg and colleagues (Zuschnegg, Schoberer, Häussl, Herzog, Russegger, Ploder *et al.*, 2023) the efficacy of *Computer-based Cognitive Interventions* (CCIs) including VR was evaluated, confirming beneficial effects on working memory, attention and concentration, and executive functions. But no significant improvement on global cognition and language was reported in subjects with MCI; in the case of dementia only a non-significant trend was detected in increasing memory functions.

As results from various reviews, *Serious Games* are increasingly used in the treatment of dementia. These prove to be more effective in the treatment of dementia when integrated in their use with the VR platform, especially in the initial and intermediate stages, compared to the advanced stage (Ning, Li, Ye, Zhang, & Liu, 2020); e.g., statistically significant effects were confirmed on physical, cognitive and emotional functioning, as well as on the performance of daily activities (Van Santen, Dröes, Holstege, Henkemans, Van Rijn, De Vries *et al.*, 2018; Voinescu, Papaioannou, Petrini, & Fraser, 2021).

The study conducted by Flynn and colleagues (Flynn, Healy, Barry, Brennan, Redfern, Houghton *et al.*, 2022b) was aimed at exploring the lived experience of elderly people with dementia and their informal caregivers with respect to the use of the *VR FOUNDations* platform, which was shown to be a useful tool for the promotion of well-being and health.

### *3.5. Degree of immersion of VR and "Augmented Reality"*

As has been reported in some studies reviewed in the literature, salient elements to be considered are the different types of environment and levels of immersion characterizing VR systems, which can be non-immersive, semi-immersive, or totally immersive (iVR).

Most VR applications for AD do not offer a Virtual Environment (VE) with sufficient levels of immersion or interaction, but mostly simple non-immersive or semi-immersive VR scenarios. Interesting data emerged in relation to an improved patient performance and above all to higher levels of adherence to daily training and rehabilitation treatment (García-Betances, Arredondo Waldmeyer, Fico, & Cabrera-Umpiérrez, 2015).

The positive effects of iVR on cognitive function are difficult to state with certainty; however, the acceptability of such technologies by patients with MCI or dementia, as well as their preference of VR over other interventions, has been demonstrated (Sayma, Tuijt, Cooper, & Walters, 2020).

Bauer and Andringa (2020) explored benefits and limitations of using iVR as a cognitive training tool on older people with cognitive decline. Among the positive aspects of iVR, they underlined the possibility of being able to simulate certain actions in safety conditions, to personalize the intervention, to reduce dependence on professional healthcare workers, and to favor training and cognitive learning. However, it emerged that its use can also cause "cybersickness", characterized by nausea, oculomotor symptoms and disorientation.

Papaioannou and colleagues (Papaioannou *et al.*, 2022) confirmed that the level of immersion in people with MCI significantly affected their global cognitive functioning.

Shin and colleagues (Shin, Kim, Bae, Kim, Park, You *et al.*, 2023) evaluated the usability and safety of fully immersive VR instrumental activities of daily training: these iVRs were useful in people with mild dementia and provided them with a high level of satisfaction, thus proving to be a valid support in the improvement of their activity of daily living skills, cognitive functioning and mood.

The importance of the ecological dimension of VR has often been emphasized (e.g., Kim, Lee, Nuseibeh, Jung, & Kim, 2022), highlighting that it leads to improvements in emotional health and quality of life. How much does immersiveness affect this ecological validity? A study by Panerai and collaborators (Panerai, Catania, Rundo, Tasca, Musso, Babiloni *et al.*, 2023), based on the rehabilitation of Functional Living Skills (FLS) through specific applications, detected how the non-immersive VR FLS (information, suitcase, medicine and supermarket) generated improvements in the daily skills trained both in the virtual and in the natural environment, confirming the ecological validity of VR. Furthermore, non-immersive virtual training causes fewer symptoms typical of the disease, such as disorientation and nausea, as well as allowing to maintain control of the surrounding environment.

A different level of virtual immersion is "Augmented Reality" (AR), a technology like virtual reality, which however superimposes stimuli, such as images and texts, on what the users perceive around them, without completely changing the characteristics of the environment and without immersing the user in a context different from the one perceived without the VR tool.

Little research has been done to demonstrate its feasibility, safety, tolerability, or evidence of its usability with the elderly population, especially with dementia; however, its potential benefits have been highlighted, such as security, ease of use, and less barriers to implementation. Compared to virtual reality, AR has, in fact, demonstrated to have a greater tolerability and fewer side effects; moreover, the fact of being a less engaging experience may be advantageous for the elderly, as it does not involve a visual-spatial detachment from their environment, leading to less perceptual confusion. Finally, AR is employed to compensate for early-stage cognitive deficits, thus offering greater chances of maintaining one's independent cognitive functioning for a longer time (Dickinson, Kimball, Fahed, Chang, Sekhon, & Vahia, 2023).

### *3.6. VR for diagnosis*

Many studies have explored the effectiveness of virtual reality as a diagnostic tool, especially in mild cognitive decline (MCI) that often progresses to dementia.

Wang and colleagues (Wang, Yin, Li, Jia, Leng, Meng *et al.*, 2020) conducted a review reporting the thematic analysis elements of discrimination of the subjects, and of the evaluated VR tasks and domains, highlighting the common peculiarities of the most widespread VR systems, such as semi-immersive VR, use of joysticks or gamepads. VR was shown to be a very effective tool in assessment as well as cognitive recovery, as it allows monitoring patient responses in real time; users get more feedback especially thanks to interactivity. By working in an ecologically efficient way, VR is more advantageous than traditional tests and tools, carrying out assessments based on tasks similar to real-life activities (Liu, Tan, Chen, Liu, Yang, & Zhang, 2019; Słyk, Zarzycki, Kocwa-Karnaś, & Domitrz, 2019).

Also iVR is increasingly configured as a valid assessment method in people with cognitive decline; in particular, a greater efficacy is highlighted if the assessment by iVR is well integrated with theoretical models of neurodegeneration and with existing screening methods. More specifically, protocols based on the use of LEAP Motion have proven to be valid and effective with MCI and AD patients (Clay, Howett, FitzGerald, Fletcher, Chan, & Price, 2020; Colombini, Duradoni, Carpi, Vagnoli, & Guazzini, 2021).

Remotely administered VR cognitive assessment tools can also be said to be reliable, feasible and with good levels of acceptability (Gosse, Kassardjian, Masellis, & Mitchell, 2021). A review compared the usability and validity of traditional vs VR diagnostic tools. The *Virtual Reality Day-Out-Task* (VR-DOT) and the *Informant Questionnaire on Cognitive Decline in the Elderly* (IQCODE) were found to be more valid and sensitive in the evaluation of the MCI, while the *Virtual Reality Technology* - *Virtual Supermarket* (VT-VSM) appeared to be more specific but less sensitive (Abd Razak, Ahmad, Chan, Kasim, Yusof, Ghani *et al.*, 2019).

Lee and colleagues (Lee, Lee, Jeon, Lee, Kim, Cho *et al.*, 2022) conducted a study aimed at testing the diagnostic efficacy of VR when integrated with a wearable EEG device, confirming that an integrated VR and EEG platform could promote a more rapid and effective diagnosis of cognitive impairment, with the positive aspects of an early diagnosis.

In evaluating the use of the *Virtual Supermarket Test* (VST), Zygouris and collaborators (Zygouris, Segkouli, Triantafylidis, Giakoumis, Tsolaki, Votis *et al.*, 2022) reported significant correlations between this test and the *System Usability Scale* (SUS) score.

Jang and colleagues (Jang, Choi, Son, Oh, Ha, Kim *et al.*, 2023) investigated the efficacy and usability of a salivary DeHydroEpiAndrosterone (DHEA) and VR cognitive assessment program for MCI screening, demonstrating the greater sensitivity and specificity of the VR program compared to traditional tools.

Topographic disorientation is known to be a frequent deficit in patients with neurological diseases. An attempt was made to verify the accuracy of spatial orientation tasks using VR devices in the diagnosis of MCI, attesting a precision and greater sensitivity, as well as a significant possibility of carrying out ecological assessments of spatial orientation (Costa, Pompeu, Viveiro, & Brucki, 2020).

As reported by the literature, the use of VR allows to empirically manipulate the information embedded in the virtual environment and allows to evaluate navigation strategies in patients with brain injury or schizophrenia, but also in the context of aging and dementia (Cognè, Taillade, N'Kaoua, Tarruella, Klinger, Larrue *et al.*, 2017). Indeed, it was found that spatial navigation performance can be used as a behavioral marker, as it contributes to the identification of patients with cognitive decline and dementia, in particular aMCI (predominantly amnesic MCI) and Alzheimer's dementia (AD).

The *Floor Maze Test* (FMT) highlighted a discriminatory effect of spatial navigation performance between healthy elderly individuals and patients with cognitive decline, while spatial navigation did not appear to influence the identification of mixed and vascular dementia (Plácido, de Almeida, Ferreira, de Oliveira Silva, Monteiro-Junior, Tangen *et al.*, 2022).

Keeping in mind that measures, such as time and spatial orientation, can detect a cognitive and motor decline due to a condition of normal old age, Chatterjee and Moussavi (2022) conducted a study to identify a more sensitive measurement parameter and to verify if this could be the measurement of error in spatial orientation, using a virtual reality system to diagnose cases of cognitive decline. The results confirmed the greater sensitivity of this parameter compared to simple distance; based on this result, Moussavi and colleagues (Moussavi, Kimura, & Lithgow, 2022) proposed and tested a spatial orientation-based VR test, confirming that it was a useful diagnostic tool to discriminate early or mild AD from MCI quickly and easily.

In the diagnostic field, VR demonstrates its continuous and rapid evolution; the study by Sasaki and collaborators (Sasaki, Oyama, Hirozane, Yamashita, Sekimoto, & Hattori, 2022), analyzing the spatial perception of patients with Parkinson's disease, confirmed the hypothesis of a visual-spatial disability and/or impairment of attention in these patients.

By introducing the evaluation of spatial performance through the *SPACE* platform, Colombo and Grübel (2023) highlighted how the tasks proposed in VR were robust enough to detect age-related decline in spatial skills.

Therefore, since spatial orientation is a cognitive domain often compromised in patients with Alzheimer's disease and one of its first clinical manifestations, an immersive virtual task was developed and validated to evaluate spatial orientation in the elderly with and without mild cognitive impairment: The *Spatial Orientation in Immersive Virtual Environment Maze Test* (SOIVET-Maze). The test showed excellent applicability and good stability, supporting clinical utility for the assessment of spatial orientation in the elderly (Silva, Santos, Costa, Moretto, Viveiro, Lopes *et al.*, 2023).

Imaoka and colleagues (Imaoka, Flury, Hauri, & de Bruin, 2022a) investigated the effects of a simultaneous VR global rating system by dual task trials, confirming the hypothesis that postural sway and eye movements are potential biomarkers for dementia assessment.

### *3.7. VR co-design*

The review by Guglietti and colleagues (Guglietti, Hobbs, & Collins-Praino, 2021) underlined that a few tricks and optimizations - such as the improvement of the feedback mechanism and the standardization of the study protocols - would be needed to achieve significant advancements, such as delaying the onset of MCI or dementia. The scientific literature in this regard highlights the importance of involving people with dementia in the system design phase to take into consideration the needs and perceptions of these people in the development of interventions based on VR technologies (Rai, Cavalcanti Barroso, Yates, Schneider, & Orrell, 2020).

More in detail, the end-users of the product should be involved in the design phase of *Head-Mounted Display-based Virtual Reality* (HMD-VR) health games so that greater efficacy could be achieved at a therapeutic level, including levels of adherence to treatment; this could be favored by a co-design process (Tao, Garrett, Taverner, Cordingley, & Sun, 2021). For these reasons, the experiences and perceptions of people with dementia regarding VR were investigated, highlighting barriers and facilitators of use; it was reported that novelty and prejudices were often limits, while support, the acknowledgment of concerns and reassurance, as well as the setting, were identified as facilitators of use.

Considering the expected increase in the coming decades of people with dementia and the need for assistance, artificial caregivers were designed using augmented reality. They are based on a machine learning system aimed at learning the patient's entire routine and assisting him/her in all daily activities, just like a human caregiver would do in safety and autonomy, but also without the continuous human supervision. Furthermore, an app is associated to a mobile device, used by a family member to keep up-to-date on the conditions of the person with dementia and alerted in the event of a fall or removal from the area designated as safe (Varghese, Gokilavani, Kunjachan, Namboodhiri, & Menezes, 2021; Flynn, Barry, Qi Koh, Reilly, Brennan, Redfern *et al.*, 2022a).

Anlacan and colleagues (Anlacan, Jamora, Pangilinan, Salido, Jacinto, Tee *et al.*, 2022) presented an innovative immersive virtual reality project, set in the Filipino culture, whose objective was the therapeutic treatment through VR of the Behavior and Psychological Symptoms of Dementia, collecting technical and design feedback, in order to improve the VR prototype employed.

Munoz and colleagues (Muñoz, Mehrabi, Li, Basharat, Middleton, Cao *et al.*, 2022), designing *Seas the Day*, a VR exergame (fitness game tracking body movements) complementary to the "Oculus Quest" viewers. The authors demonstrated that collaboration between multiple stakeholders produced good results, such as the production of VR games more personalized and sensitive to the needs of people with dementia, thanks to the work of interaction and feedback from recipient users and therapists.

### *3.8. Training of caregivers*

It is important that both formal and informal caregivers are deeply aware and trained to guarantee the right care and assistance to patients with cognitive decline. Hirt and Beer (2020) underlined that VR has the potential to be an effective intervention to train patient caregivers, while further studies are needed on the use and impact of VR in education.

As Petrovich's (2022) study shows, the *Virtual Dementia Experience* (VDE) is a powerful advocacy tool for engaging the population in raising awareness about dementia, and the impact it has on people.

The usefulness of VR as a training tool has also been confirmed by informal caregivers, who reported having received various benefits from the use of technological supports, especially thanks to the figure of professionals who act as mediators (Armstrong & Alliance, 2019). Song and collaborators (Song, Cheon, Kim, Jung, Kim, Yang *et al.*, 2022) investigated the effects of an educational program based on VR / MR (Virtual Reality / Mixed Reality) technology for the management of *Behavior and Psychological Symptoms of Dementia* (BPSD), i.e. a VR-EduBPSD. An excellent potential to improve the preparation and skills of family members of people with dementia to manage BPSD emerged from the results.

Most family members showed that they know how to use electronic devices and prefer "Open" VR, based on the use of a flat screen via smartphone, compared to "Closed" VR, based on the use of a headset; they also showed interest and intention to reuse virtual reality systems in the future (Cheon, Jung, Kim, Yang, Kim, & Song, 2022).

The use of iVR and Augmented Reality has the potential to improve the knowledge, attitudes, empathy and sensitivity of healthcare professionals and trainees (Jones, Jones, & Moro, 2021). In this regard, simulation-based training courses allow healthcare professionals to learn and practice new knowledge in a safe environment (Sampson & Goldberg, 2022).

Yamaguchi and colleagues (Yamaguchi, Ryuno, Fukuda, Kabaya, Isowa, Hiramatsu *et al.*, 2022) evaluated the effectiveness that VR could have for dementia care education in Japanese nurses, demonstrating that it can improve care skills and attitudes towards people with dementia. These findings demonstrated the effectiveness of VR-based education programs to increase knowledge and empathy of dementia caregivers (Campbell, Lugger, Sigler, & Turkelson, 2021; Sung, Su, Lee, Yamakawa, & Wang, 2022).

Hicks and colleagues (Hicks, Konovalova, Myers, Falconer, & Board, 2023) conducted an exploratory qualitative study designed to enhance the experiences of nursing home professionals through the VR application “A walk through dementia”. While these experiences appeared to be important for professionals wishing to use VR in dementia care, at the same time the utility of providing a captivating, immersive and realistic experience emerged, which could allow professionals to understand the lived emotional narratives of a person with dementia. VR was therefore confirmed as an experiential tool that increased the awareness of dementia in those taking care of it.

Kobayashi and collaborators (Kobayashi, Iwamoto, Une, Kurazume, Nakazawa, & Honda, 2022) evaluated the effectiveness of simulated training in communication skills also for nursing students, using augmented reality with real-time feedback, and demonstrated that it increased interactive communication and empathy towards patients. Students reported a significant improvement in understanding about how their lives would be affected by dementia and about caring for people with dementia; in general, they considered this simulation useful for clinical purposes, suggesting its inclusion in curricular programs to integrate virtual reality into medical therapies (Bard, Chung, Shaia, Wellman, & Elzie, 2023). According to Torrence and colleagues (Torrence, Bhanu, Bertrand, Dye, Truong, & Madathil, 2023), when comparing mixed training on Alzheimer's disease attention deficits that physically alter sensations, the effectiveness of VR was equivalent to direct, physical intervention; the qualitative results showed improvements in the levels of empathy.

Furthermore, the usefulness of VR for caregivers has been widely demonstrated to increase awareness of the real needs of people with dementia, and to arrange environments in an optimal way to satisfy these needs (Stargatt, Doube, Bhar, Petrovich, McGuire, & Willison, 2022).

Table 1 summarizes the articles considered in the review distinguished by type and categories of variables used for the selection.

Table 1 – *Summary of the areas explored by the review, type of studies included, number and type of samples included, and type of virtual reality used*

| Area | Authors (Year) | Type of study (a) | Sample (b) | Type of sample (c) | Type of Virtual Reality (d) |
|---|---|---|---|---|---|
| Diagnosis *N* = 19 | Cognè *et al.* (2017) | R | K = 63 | D | VR |
| | Abd Razak *et al.* (2019) | R | K = 30 | D; MCI | VR |
| | Liu *et al.* (2019) | R | K = 9 | MCI; D | siVR |
| | Słyk *et al.* (2019) | R | K = 205 | UCD | siVR |
| | Clay *et al.* (2020) | R | K = 9 | MCI | iVR |
| | Costa *et al.* (2020) | R | K = 7 | MCI | VR |
| | Wang *et al.* (2020) | R | K = 28 | MCI; D | siVR |
| | Colombini *et al.* (2021) | R | K = 19 | D; MCI | iVR |
| | Gosse *et al.* (2021) | R | K = 26 | D; MCI | niVR |
| | Chatterjee & Moussavi (2022) | S | N = 20 | MCI | VR |
| | Imaoka *et al.* (2022a) | S | N = 20 | D | VR |
| | Lee *et al.* (2022) | S | N = 59 | MCI | VR |
| | Moussavi *et al.* (2022) | S | N = 93 | D; MCI | VR |
| | Plácido *et al.* (2022) | R | K = 24 | MCI; D | VR |
| | Sasaki *et al.* (2022) | S | N = 48 | PD | VR |
| | Zygouris *et al.* (2022) | S | N = 57 | D; MCI | VR |
| | Colombo e Grübel (2023) | S | ns | MCI; D | VR |
| | Jang *et al.* (2023) | S | N = 120 | MCI | VR |
| | Silva *et al.* (2023) | S | N = 43 | D | VR |
| Rehabilitation *N* = 63 | García-Betances *et al.* (2015) | R | K = 27 | D | niVR; siVR; iVR |
| | Hill *et al.* (2017) | R | K = 25 | MCI; D | niVR; iVR |
| | Wajda *et al.* (2017) | R | K = 21 | MCI; AD; PD | VR |
| | Chiu *et al.* (2018) | R | K = 11 | D | VR |
| | Díaz Pérez & Flórez Lozano (2018) | R | K = 10 | D | VR |
| | Montero-Odasso & Speechley (2018) | R | K = 17 | MCI; D; PD | VR |
| | Van Santen *et al.* (2018) | R | K = 3 | D | VR |
| | Andringa *et al.*(2019) | R | K = 8 | D | VR |
| | D'Cunha *et al.* (2019) | R | K = 10 | D; MCI | VR; AR |
| | Liao *et al.* (2019) | S | N = 34 | MCI | VR |
| | Maggio *et al.* (2019) | R | ns | D; PD | VR |
| | Moreno *et al.* (2019) | R | K = 22 | MCI; D | VR |
| | Moye (2019) | R | K = 13 | D | niVR; iVR |
| | Riva & Gaggioli (2019) | DA | ns | D | VR |
| | Uwajeh *et al.* (2019) | R | K = 29 | D | iVR |
| | Bauer e Andringa (2020) | R | ns | D | iVR |
| | Cibeira *et al.* (2020) | R | K = 15 | D | VR |
| | Ning *et al.* (2020) | R | K = 18 | D | niVR |
| | Sayma *et al.* (2020) | R | K = 5 | MCI, D | iVR |
| | Sobral & Pestana (2020) | R | K = 356 | D | VR |
| | Tuena *et al.* (2020) | R | K = 25 | D | niVR |
| | Appel *et al.* (2021) | R | K = 18 | D | iVR |
| | Arlati *et al.* (2021) | S | N = 58 | MCI | iVR |

| | | | | | |
|---|---|---|---|---|---|
| | Jahn *et al.* (2021) | R | K = 9 | D | VR; iVR |
| | Jung *et al.* (2021) | R | K = 18 | D; MCI | VR; niVR |
| | Voinescu *et al.* (2021) | R | K = 10 | MCI | niVR |
| | Zhong *et al.* (2021) | R | K = 17 | MCI | VR |
| | Zhu *et al.* (2021) | R | K = 11 | MCI; D | VR |
| | Afifi *et al.* (2022) | S | N = 22 | D; MCI | VR |
| | Bacanoiu & Danoiu (2022) | R | K = 34 | D; PD | VR |
| | Brimelow *et al.* (2022) | S | N = 25 | D | VR |
| | Domenicucci *et al.* (2022) | R | K = 47 | D; MCI | VR |
| | Flynn *et al.* (2022b) | S | N = 18 | D | VR |
| | Fuchs (2022) | DA | NS | D | iVR |
| | Gambella *et al.* (2022) | S | N = 78 | D | VR, niVR |
| | Gruber *et al.* (2022) | S | N = 17 | D | VR |
| | Huang & Yang (2022) | S | N = 20 | D | iVR |
| | Imaoka *et al.* (2022b) | S | N = 23 | MCI | VR |
| | Kim *et al.* (2022) | S | N = 11 | D | VR |
| | Li *et al.* (2022) | R | K = 30 | D | VR |
| | Matsangidou *et al.* (2022) | S | N = 75 | D | VR |
| | Papaioannou *et al.* (2022) | R | K = 40 | MCI; D | iVR |
| | Park (2022) | S | N = 32 | MCI | VR |
| | Park *et al.* (2022) | S | N = 60 | MCI; D | VR |
| | Preston & Padala (2022) | DA | ns | MCI; D | VR; iVR |
| | Qiu *et al.* (2022) | S | N = 14 | D | VR |
| | Reisinho *et al.* (2022) | R | K = 7 | MCI; D | iVR |
| | Sun *et al.* (2022) | S | N = 10 | D | niVR |
| | Tuena *et al.* (2022) | S | N = 8 | MCI | iVR |
| | Vellani *et al.* (2022) | S | N = 42 | D | VR |
| | Walden & Feliciano (2022) | S | N = 2 | D | VR |
| | Yan *et al.* (2022) | R | K = 7 | MCI | VR |
| | Zhu *et al.* (2022) | S | N = 31 | MCI; D | iVR |
| | Dickinson *et al.* (2023) | R | NS | D; AD, IC | AR; VR |
| | Liu *et al.* (2023) | R | K = 11 | D | iVR |
| | Mancuso *et al.* (2023) | R | K = 22 | MCI | VR |
| | Matsangidou *et al.* (2023) | S | N = 30 | D | VR |
| | Panerai *et al.* (2023) | S | N = 67 | D; PD | niVR |
| | Perra *et al.* (2023) | R | K = 11 | D | iVR |
| | Shin *et al.* (2023) | S | N = 7 | D | iVR |
| | Spano *et al.* (2023) | R | K = 59 | D | iVR |
| | Tuena *et al.* (2023) | R | K = 8 | D | VR |
| | Zuschnegg *et al.* (2023) | R | K = 24 | MCI; D | niVR; VR |
| Formation N = 15 | Armstrong & Alliance (2019) | R | K = 87 | IC | VR |
| | Hirt & Beer (2020) | R | K = 6 | FC; NS | VR |
| | Campbell *et al.* (2021) | S | N = 163 | NS | VR |
| | Jones *et al.* (2021) | R | K = 19 | FC | iVR; AR |
| | Bard *et al.* (2023) | S | N = 150 | MS | VR |
| | Cheon *et al.* (2022) | S | N = 136 | IC | VR |
| | Hicks *et al.* (2023) | S | N = 20 | FC | VR |
| | Kobayashi *et al.* (2022) | S | N = 25 | NS | AR |
| | Petrovich (2022) | S | NS | US | VR |

| | | | | | |
|---|---|---|---|---|---|
| | Sampson & Goldberg (2022) | S | NS | FC | VR |
| | Song *et al.*(2022) | S | N = 10 | IC | iVR |
| | Sung *et al.* (2022) | S | N = 124 | FC | VR |
| | Stargatt *et al.* (2022) | S | N = 96 | FC | VR |
| | Torrence *et al.* (2023) | S | N = 41 | US | VR |
| | Yamaguchi *et al.* (2022) | S | N = 39 | FC | VR |
| Project N = 7 | Rai *et al.* (2020) | R | K = 21 | D | VR |
| | Guglietti *et al.* (2021) | R | K = 25 | PD; D; MCI | niVR |
| | Tao *et al.* (2021) | R | K = 29 | D | iVR |
| | Varghese *et al.* (2021) | S | ns | D | AR |
| | Anlacan *et al.* (2022) | S | ns | D | iVR |
| | Flynn *et al.* (2022a) | R | K = 14 | D | VR |
| | Muñoz *et al.* (2022) | S | N = 7 | D; MCI | iVR; niVR |

Legend:
Type of study: DA = Descriptive Article or Book; R = Review; S = single study
Sample: K if Review; N if Study; ns = not specified
Type of sample (Pathologies): AD = Alzheimer's Disease; D = Dementia; MCI = Mild Cognitive Impairment; PD = Parkinson's disease; UCD = Unspecified Cognitive Deterioration
Type of sample (Formation): FC = Formal caregivers; IC = Informal caregivers; MS = Medicine Students; NS = Nursing students; US = unspecified students
Type of virtual reality: AR = Augmented Reality; iVR = Full-Immersive; niVR = Non-Immersive; siVR = Semi-Immersive; VR = Unspecified or mixed VR

# 4. Conclusions

VR can be a useful means of proposing activities to elderly people with cognitive impairment that maintain or strengthen cognitive and motor skills but also guarantee safety and self-efficacy, in a pleasant and suitably monitored environment, and with the constant feedback on the control of the situation. It is also possible to encourage the aspects of collaboration or competition in couple or group games, thus also supporting social interactions.

Empirical research is attempting to systematically define the most appropriate characteristics of exercises in virtual environments (e.g., the degree of immersion or the use of augmented reality) to have greater efficacy both in dementia and in MCI.

At the same time, the usability and acceptability characteristics of VR by elderly people with deterioration are ascertained, proposing methods of co-design to respond to the specific needs of each user.

Another research trend has demonstrated the utility of VR for the assessment and diagnosis of deterioration and of precursors of dementia, especially in association with other tools.

Finally, the importance of training must be reaffirmed to ensure the optimal collaboration of operators and caregivers for the effectiveness of VR in working with the cognitive impairment of the elderly.

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