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Technologies Designed to Assist Individuals with Cognitive Impairments

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Abstract: Information Technology (IT) plays a vital role in promoting sustainability and enabling independent living. People with cognitive disabilities face numerous challenges in their daily lives, such as social interactions, learning new things, and improving specific abilities. A variety of therapies and treatments have been introduced to help address these challenges. Recently, computer-assisted therapeutic procedures, treatment procedures, and assistive systems have emerged as beneficial tools to improve the lives of people with cognitive disabilities. Advances in technology have made it possible to develop effective applications specifically designed for this group of individuals. The objective of this paper is to identify potential applications of these developed solutions for people with cognitive disabilities, evaluate their effectiveness, strengths, and limitations, and understand their contribution in addressing various difficulties due to cognitive impairments. To achieve this goal, we reviewed 23 studies that demonstrate several applications developed for people with cognitive disabilities to address their unique issues. Our investigation indicates that the developed applications hold promise, although a few issues with cost-effectiveness, device transparency, and specific disability dependency may limit their effectiveness. Hence, this paper aims to shed light on these innovative applications, their implications, and their role in aiding users in tackling their specific challenges.

Keywords: cognitive disability; assistive devices; memory problem; dementia; AR/VR applications; mobile applications; skill development

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1. Introduction

In today's world, a sustainable society endeavors to meet the needs of its present inhabitants without compromising the ability of future generations to fulfill their own requirements. Information Technology (IT) has emerged as a pivotal force in fostering sustainability and enabling independent living within such a society. As we progress into this technological era, it becomes increasingly apparent that physical impairments, such as vision impairment, cognitive disabilities, and mobility issues, can significantly challenge individuals who lack adequate support in their daily lives [1]. Globally, statistics reveal that a staggering 1.3 billion people, or 1 in 6 individuals, contend with substantial disabilities (as per the WHO) [2]. With an aging population and an increasing life expectancy worldwide, this number is projected to rise. Therefore, it is imperative that we address the needs of this growing demographic to enhance their quality of life.

Among the diverse spectrum of disabilities, cognitive impairment stands out as a particularly complex challenge. Cognitive disability encompasses a range of specific issues, including memory disorders, dementia, social skill deficits, autism spectrum disorder, and

the cognitive consequences of conditions like stroke [3]. According to healthcare professionals, traditional medical interventions, including therapy, can be prohibitively costly. Moreover, these therapeutic processes often necessitate additional assistance, imposing burdens on both users and practitioners [4]. To ameliorate these challenges, researchers and technologists are increasingly integrating various technologies, including Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI), robotics, mobile devices, and smart technology.

The objective of these technologies are to enhance the daily living activities of individuals with cognitive disabilities, making therapy and support more accessible and effective. In the realm of healthcare, IT has evolved into an integral component, facilitating efficient patient data management, secure information exchange, and the development of personalized treatments. Its applications encompass electronic health records, telemedicine, remote monitoring, digital tools for patient engagement, healthcare analytics, and rehabilitation. IT not only elevates the quality of healthcare but also reduces costs, promoting efficiency and personalization in healthcare delivery [5].

For instance, memory disorders resulting from brain damage pose significant challenges in forming, retaining, and recalling memories. These disorders can arise from various causes, including trauma, stroke, infections, and adverse reactions to medication. Traditional pharmacological treatments can be costly and entail adverse effects. In this context, game-based psychotherapy has emerged as a promising intervention for elderly individuals with memory disorders, offering a cost-effective and potentially side-effect-free alternative [6]. Similarly, dementia, a progressive neurodegenerative disorder affecting over 46 million people worldwide, is typically addressed through a combination of pharmacological and non-pharmacological interventions. Among the latter, game-based interventions involving mentally stimulating games have demonstrated potential in improving cognitive function, memory, and motor reactions.

Furthermore, stroke, also known as cerebrovascular accident (CVA), remains a significant global cause of mortality and disability, particularly affecting hand functionality. Although traditional treatment methods require regular, ongoing physical therapy in specialized institutions or hospitals, advances in robotics and smart technologies have given rise to innovative approaches. Game-based training protocols, particularly those incorporating Virtual Reality (VR), have proven effective in enhancing patient motivation and engagement during rehabilitation. Nevertheless, more research is needed to tailor games to the specific needs of stroke patients with hand disorders and to develop cost-effective, user-friendly, and easily accessible community and home-use rehabilitation devices and technologies [7]. Given the dramatic rise in the number of people with disabilities, particularly cognitive disabilities, the importance of providing robust support and care has never been more pronounced. In recent years, several novel methods have emerged, utilizing advanced and smart technologies to enhance the competence and independence of individuals with disabilities. These innovative developments fall under the umbrella of assistive technologies (ATs), offering the potential for improved quality of life at a reduced cost compared to conventional procedures. This article seeks to delve into the advancements in assistive technologies (ATs) related to cognitive disabilities, addressing the challenges of integration into daily life, potential barriers to implementation, and pertinent legal considerations.

By adopting this revised structure, we aim to provide a more focused and coherent exploration of cognitive disabilities, their impact on specific functions of information processing, and the evolving solutions designed to address these challenges.

2. Methodology

In this research, we are seeking the answers for the following research questions:

- Can IT solutions be used as a home-based alternative therapy?
- Can IT solutions be considered as a reliable assessment that evaluates memory functions?

- What are the advantages of IT solutions compared to clinical devices? Is it more cost-efficient to use IT solutions when compared to clinical devices?
- How can AI be used in healthcare?

We first searched the literature using selected keywords in five databases: Web of Science, Google Scholar, Scopus, ScienceDirect, and PubMed. The literature search was performed with the aim of investigating assistive technologies or tools for people with cognitive disabilities or cognitive aspects. Additionally, our focus was to include the computerized tools that are utilized for any kind of skill development for every group of people (males, females, adults, children, older individuals, etc.) with cognitive disabilities (motor problems, autism spectrum disorder (ASD), learning disabilities, etc.). We set the search period for literature selection at between January 2015 and February 2023, using several search keywords such as 'assistive technologies', 'assistive tools', 'assistive tools for cognitive impairment', 'automated assisting with people with cognitive aspects', 'improving cognitive difficulty', 'helping people with cognitive disability', and 'AI applications in memory rehabilitation'.

In total, a list of 132 studies was identified from database searching and other sources. After literature collection, pre-processing was performed: duplicate papers were removed, those studies that were not in English were also removed, and those papers that were not possible to freely access or download were removed as well. After the primary screening, 90 papers were removed from this research and 42 papers were selected initially. Before the final selection, we performed another screening with the aim of assessing the relevancy of papers to the research aims. Among 42 papers, we excluded 19 papers that were not directly related to cognitive aspects or assistive technology. Most of these were investigations or literature reviews regarding other disability types, while some detailed only the experimental process, not the developed solution. Finally, we included 23 papers in this research study. Figure 1 shows the article selection process in detail based on a PRISMA flowchart. PRISMA is an evidence-based item selection or reporting process for systematic reviews and meta-analyses.

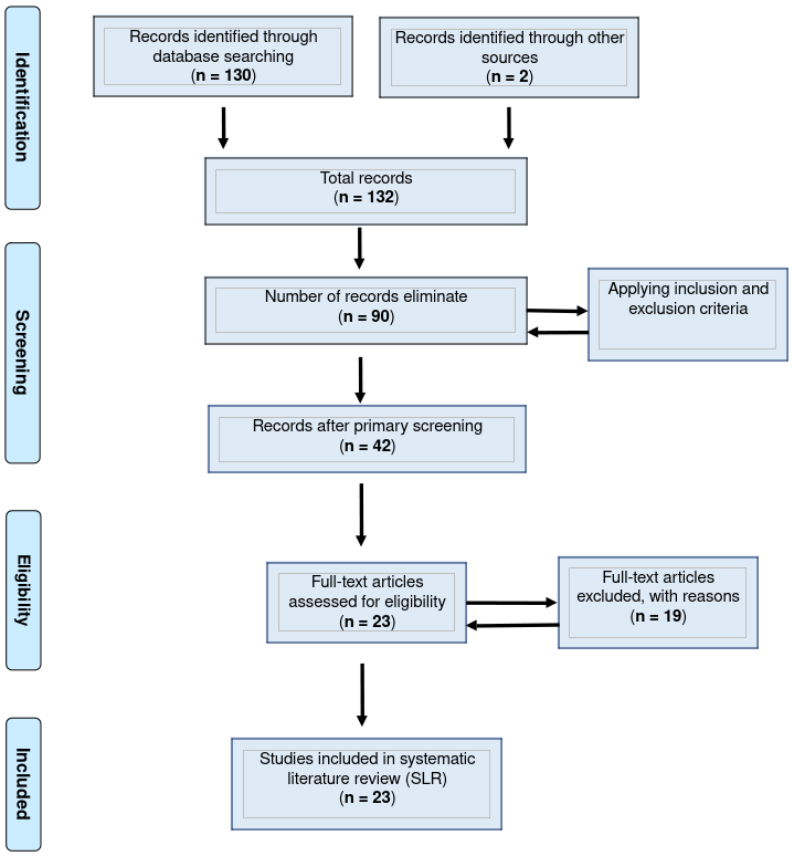

Figure 1. Study selection process illustrated using a PRISMA flowchart.

3. Evaluation Results

From the observation of the selected studies, we classified the selected papers into two categories: 'Assistive technologies for memory improvement' and 'Assistive technologies for assisting daily activities'. The aims of the papers within these two AT categories are to help people with physical disability; however, one included those dedicated only to people who need therapy after a certain situation, such as a brain injury or broken hand, etc., while the other included those dedicated to people with long-term disability (for example, children with ASD). All of these ATs were developed to focus on several technologies, such as Virtual Reality-based assistive technologies, mobile application-based assistive technologies, wearable technology-based assistive technologies, context-aware assistive technologies, computing device-based assistive technologies, etc. A summary of the reviewed studies in terms of their bibliographic information, objective, target users, challenges, and limitations have been listed in Table 1. In the following bubble chart, in Figure 2, we can see the strengths and limitations of the main assistive technologies included in this research.

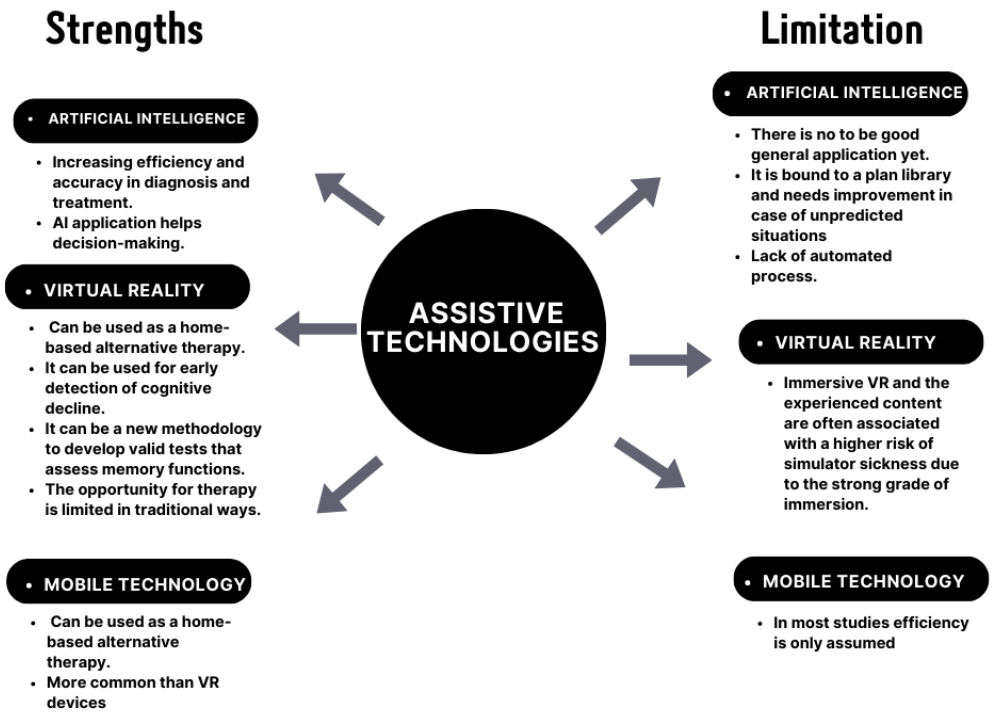

Figure 2. Bubble chart of assistive technologies' strengths and limitations.

ChePa et al. [8] proposed game-based psychotherapy as an alternative to costly pharmacological treatments for memory disorders, as it can stimulate brain activity and help individuals recall memories. This study tested the effectiveness of Neuro-therapy, a puzzle-based game, in an intervention program with a group of elderly individuals exhibiting memory disorder symptoms. The results showed positive impacts on cognitive improvement, memory recall, and IT literacy. Eight dimensions of cognitive improvement were identified based on the performance metrics of the EEG reader headset, such as engagement, relaxation, stress, focus, excitement, and interest. This study has demonstrated the effectiveness of combining game-based interventions with psychotherapy for elderly people with memory impairment symptoms.

Table 1. Summary of the investigated studies.

Ref	Year	Population Group	Technology	Target Users	Devices	Type of AT	Objective	Strengths	Limitation
[8]	2022	Elderly with memory disorder, both sexes	Mobile technology	-Elderly with memory disorder	Mobile phone	Visual memory	Game-based psychotherapy for elderly individuals with memory disorder symptoms	-Alternative treatment	---
[9]	2022	Healthy, mean age: 36.64, both sexes	Virtual Reality	-Healthy people, -Alzheimer's patients -Other memory disorders	VR headset	Memory assessment and memory training	Memory assessment with a Virtual Reality-based system to check for any associations between performance and age, performance and years of education, and reaction time and age	-It can be used for early detection of cognitive decline. -It can be used as a new methodology to develop valid tests that assess memory functions reliably and efficiently and within ecologically valid contexts	-It must first be validated through a randomized control trial, and checked to see if it can be used in the clinical environment as well
[10]	2022	Major Depressive Disorder, mean age: 25, both sexes	Virtual Reality	-Patients with Major Depressive Disorder	VR headset	Event-based Prospective Memory training	Virtual Reality (VR)-based Working Memory Training (WMT) to improve Event-based Prospective Memory (EBPM) deficits in patients with Major Depressive Disorder (MDD)	-Opportunities for use in therapy, which are limited using traditional methods	-Comparatively small sample so this study cannot confirm the long-term effects of VR
[11]	2022	Healthy, mean age: 21, both sexes	Virtual Reality	--	VR headset and EEG	Visual working memory	Investigate cueing, memory encoding, maintenance, and retrieval in VR	-Facilitating the understanding of the working memory	--
[12]	2018	Healthy patients and patients with cognitive decline, younger adults with mean age: 21.65, older adults with mean age: 68, both sexes	Virtual Reality	-Patients with cognitive decline	VR devices: headset and pointing device	Everyday memory	To assess everyday memory performance more accurately	Neuropsychologists can assess everyday memory performance more accurately. -Close to real-life situations	--
[13]	2019	Dementia, older age, both sexes	Virtual Reality	-Patients diagnosed with dementia and other neurodegenerative diseases, including Alzheimer's.	VR headset	Improving spatial memory	3D virtual environment-based serious game for assessing dementia patients with low cost	-Lower cost than clinical devices (e.g., MRI scans). -Interactive, 3D virtual environment	--
[14]	2021	Stroke patients, mean age: 68.3, both sexes	Virtual Reality	-Older adults, including those who have had strokes	Head-Mounted Display Virtual Reality device and pointing device	Improving cognitive abilities following a stroke	Improving self-reported cybersickness and performance in memory span and speed tasks in stroke patients	-Treatment provided by immersive HMD-VR	-Immersive VR and the experienced content are often associated with a higher risk of simulator sickness due to the strong grade of immersion, which could be a limitation for the use of immersive VR in different settings

Table 1. *Cont.*

Ref	Year	Population Group	Technology	Target Users	Devices	Type of AT	Objective	Strengths	Limitation
[15]	2016	Stroke patients, mean age: 65, both sexes	Virtual Reality	--	VR headset	Prospective Memory	Improving Prospective Memory (PM) through a Virtual Reality (VR) environment using Constraint-Based Modeling (CBM) and individual feedback	-Adaptive training requires significant clinical input and requires variables to be strictly controlled, which are difficult to control for human investigators and can be replaced with VR	---
[16]	2015	All people	Mobile technology	-All people	Mobile phone	Memorizing semantic declarative facts	Helping with memorizing semantic declarative facts to aid students	-More entertaining and effective as it is a music-based memory-support tool	-Not finished yet—only a pilot version was tested
[17]	2021	All people	Mobile technology	-All people	Mobile phone	Developing everyday-life memory	A prototype was designed to improve usability, enjoyment, and difficulty of game design to raise awareness of COVID-19 information and provide entertainment	-It was developed for mobile platforms, which are more common than VR devices	-Only English language is available
[18]	2017	Healthy people, 6–12-year-old students, both sexes	Mobile technology	-6–12-year-old students	Mobile phone	Mnemonic	Gamification and mnemonic methods (memory development) to aid children in learning Chinese	-Game is effective in creating an interest	---
[19]	2021	Patients with dementia	Measurement of eye movement using tangram	-Patients with dementia	Eye tracking device	Short-term memory	Development of a simple puzzle game to measure eye movement to evaluate cognitive function	-Reducing the burden of testing on medical staff and elderly people. -In the case of dementia, the patient's symptoms can be improved by early detection and medication	-Only available in clinical settings
[20]	2019	Students, male and female, 10–11 years old	Peer-assisted instruction (PAI); iPad-assisted instruction (IAI)	-Students with reading learning disabilities (RLDs)	iPad	AT for improving reading fluency	Understanding students' reading abilities and improvement requirements	-Implementation of a PAI and IAI combined approach	-Experimented using a single device -Limited number of participants
[21]	2017	Students, male and female, 14–19 years old	A tubular structure material with thermoplastic PVC polymer	-Adolescents with cerebral palsy	---	AT for assisting adolescents with cerebral palsy to overcome their daily difficulties with studying	Supporting the educational activities of adolescents with cerebral palsy with low cost	-Implemented and validated with educator	-Limited number of participants
[22]	2019	Children, male, 8 years old	--	-Children with cerebral palsy	NAO robot	AT for assisting children with cerebral palsy to sit, stand, walk, run, and jump independently	Improving the therapeutic process for motor learning (i.e., walking) using a social assistive robot	-SMART-focused (Specific, Measurable, Achievable, Realistic, and Timed)	-Lack of validation with real therapist

Table 1. *Cont.*

Ref	Year	Population Group	Technology	Target Users	Devices	Type of AT	Objective	Strengths	Limitation
[23]	2019	Older adults, male and female, 72–94 years old	Electric calendar	-Older adults with dementia	Tablet	AT for improving cognitive function and behaviors in daily activities	Assessing the effectiveness of using an electric calendar as an assistive technology for older adults with dementia	-Consideration of several aspects such as global cognitive function level, daily activities, appropriate support, and motivation	-Considered only dementia—other cognitive levels should be considered
[24]	2019	Young adults	--	-People with traumatic brain injury	---	AT for assisting meal preparation or cooking	Design and development of a cognition context-aware assistive technology	-Focused on user-centred design (UCD)	-Focus on specific disability
[25]	2018	Young adults, 18–27 years old	Wearable technology	-People with intellectual and development disability	Smart watch app	AT for encouraging students' self-regulation and positive behaviors	Assisting IDD students to improve their behavioural activity using wearable assistive technology	-Consideration of wearable technology	-Consideration of a single device
[26]	2018	All people	Decision support system	-People with decision-making difficulty	--	AT for supporting people with cognitive disabilities to make their own decisions across life	Assisting brain injury-affected or intellectually disabled people in decision making	-Evidence-based support for decision-making practice	-Lack of automated process
[27]	2019	Children	Kinect V2 sensor	-People with intellectual disabilities (ID)	Lenovo Thinkpad T61 notebook computer Microsoft Windows 7	AT for assisting children with ID in hand washing independently	Assisting children with intellectual disabilities to improve their hand hygiene skills	-Teaching with video game	-Limited number of participants for experiment
[28]	2010	Male and female, 85+ years old	Cognitive orthosis	People with dementia	COACH	-	Providing AI-based tools to help people with disabilities in their day-to-day life	Hardware that tracks user actions and an AI application that helps decision-making	-It is bound to a plan library and needs improvement in case of unpredicted situations
[29]	2016	-	Super clinician	Any clinical patients	-	-	AI-based assistant to practitioners during clinical assessments and treatments	Increasing efficiency and accuracy in diagnosis and treatment	-There is no good general application yet
[30]	2021	-	Memorz Stash Alzheimer's Aid	People with Alzheimer's syndrome	Android	-	An application for mobile devices that may help with memory problems	AI- and non-AI-based app that aims to slow down memory loss and maintain reasoning ability	-Results are not tested -Efficiency is only assumed

With the aim of memory improvement, Varela-Aldás [9] noted that VR has been shown to be a valuable tool in cognitive rehabilitation, with the ability to create a virtual environment that can replicate physical activities. Their aim was to present the use of VR in evaluating memory by using an Immersive Virtual Reality (IVR) application known as the Cupboard task. This task is based on an activity of daily living (ADL) and is designed to provide a more ecological way to evaluate memory skills. Their study showed that it is possible to use an IVR application to successfully assess everyday memory. The results obtained suggest good construct validity, with a high degree of concordance between both memory performance measures. Correlations between performance and age, performance and years of education, and reaction time and age were found, as well as gender differences in performance. The degree of usability was very high according to the test carried out by the participants. The results open the door to its use in clinical settings for cognitive training of patients with mild cognitive impairment or severe cognitive impairment such as Alzheimer's or dementia, although first its efficacy must be validated through a randomized controlled trial.

Huang et al. [10] claimed that Event-based Prospective Memory (EBPM) deficits are present in patients with Major Depressive Disorder (MDD) and impede recovery. Thus, Virtual Reality (VR)-based Working Memory Training (WMT) has been suggested as a way to enhance EBPM. They investigated the effectiveness of VR-based WMT in MDD patients, with 46 MDD patients and 41 healthy participants included. The results showed an increase in the EBPM accuracy of the MDD-VR group post-VR intervention, while there was no significant group-by-time interaction or group effect on the Hamilton Depression Rating Scale (HDRS) score. The results indicate that VR-based WMT could improve EBPM deficits in MDD patients, and further large-scale studies are recommended.

Gregory et al. [11] presented an experimental process with 47 participants using a 64-channel eegoTM sports mobile EEG system during a visual working memory task presented in VR with an Oculus Rift S head-mounted display. In the memory task, participants had to remember the status of and details about objects presented on a table. Prior to the object's appearance, a moving, 3D social avatar or non-social stick cue was presented, pointing to the left or right of the table. Data included raw and processed EEG, as well as behavioral data, and the task was set up to allow the investigation of neural signals during attention cueing and memory encoding, maintenance, and retrieval. The main novelty of the dataset is the presentation of the social avatar and non-social stick cue in VR within subjects, allowing comparison across time points, including a period of eye contact. The data are also of interest to researchers interested in the neural correlates of working memory and combining VR and EEG.

Ouellet et al. [12] claimed that Virtual Shop could be a fully immersive task development process to assess memory in a more ecological way than traditional neuropsychological assessments. They performed two studies to assess the feasibility of the task and to examine its validity. In study one, 20 younger and 19 older adults completed the task, and the contrast group method was used to compare their performance. In study two, 35 individuals with subjective cognitive decline completed the Virtual Shop, and performance was correlated with both an existing questionnaire and traditional memory and executive tasks. Results showed that the task had an appropriate level of difficulty for differentiating between younger and older adults, and that performance on the task was significantly and moderately correlated with performance on the questionnaire and traditional tasks. These results support the feasibility as well as the ecological and construct validity of the Virtual Shop.

The opinion of Bayahya et al. [13] is that the traditional clinic tests that rely on high-cost devices such as MRI scans in hospitals to diagnose dementia and other neurodegenerative diseases are becoming increasingly expensive and inefficient. Therefore, there is an urgent requirement to explore new, automated techniques to assess and diagnose such conditions. Thus, they proposed a solution to use virtual environments as a psychological test platform, which provides a controlled environment for patients to interact with and in which to be

assessed. They introduced a 3D virtual environment platform that was used to develop an interactive, cognitive electronic test for dementia assessment. Their provided solution yields a more efficient and cost-effective process that can be used to accurately assess and diagnose dementia. The solution is designed to be interactive and immersive, enabling patients to engage in activities that help to accurately assess their cognitive abilities.

Specht et al. [14] stated that VR is becoming increasingly accessible, and its applications in clinical settings are growing. Their study aimed to investigate the acceptance of Head-Mounted Display Virtual Reality (HMD-VR) systems in stroke patients, as well as a control group of healthy age-matched adults. Results showed that both groups had positive attitudes towards HMD-VR and reported positive user experiences in the VR setting. Controls had higher and more homogeneous scores in user experience, and performed faster in the VR tasks, while there were no significant differences in memory span. They suggested that immersive HMD-VR is tolerated by older adults, including those who have had strokes, without prior acquaintance with the VR device or software, and without being hindered by negative attitudes towards VR or cyber sickness. Thus, VR may be a potentially effective, engaging, and economic way to improve cognitive abilities following a stroke.

Mathewsa et al. [15] noted that Prospective Memory (PM) is a crucial form of memory for everyday life which can be impaired in stroke survivors and interfere with independent living. To help improve PM skills, a computer-based treatment has been developed, which uses visual imagery to teach the participants. After the treatment, the participants practiced their PM skills using videos, and then in a VR environment. This VR environment uses Constraint-Based Modeling (CBM) to track user actions and provide feedback. This study involved 15 stroke survivors and shows that this treatment procedure is highly effective. The participants showed a significant improvement in their ability to remember time- and Event-based Prospective Memory tasks. This treatment process is a great example of how technology can be used to help people with memory impairments live a more independent and meaningful life.

Ow et al. [16] developed a music-based AT that was composed specifically to aid students in memorizing semantic declarative facts. In order to test its effectiveness, a pilot study was conducted, and the results were encouraging. Constructive feedback was obtained to guide the development of the mobile application, which was created based on the pilot study results. The app has the potential to become a widely accessible and automated memory support tool. Preliminary studies have demonstrated that it can effectively help students to remember semantic declarative facts. The future improvements of the app will be based on the constructive feedback received, as well as on further research into the effectiveness of music-based memory-support tools.

Yonathan et al. [17] described the rapid growth of the gaming industry and its development into one of the most influential industries in the world. In this study, a prototype was created to improve the game design in terms of usability, enjoyment, and difficulty. Furthermore, this prototype was also designed to provide fun as well as raise awareness about COVID-19. In order to achieve their aim, the literature was studied, and a questionnaire was conducted to gather user requirements. A prototype was then created to introduce the design, with the aim of having users benefit from the design by improving their hygiene habits to stay healthy in the midst of the pandemic. This prototype aimed for the users to gain the benefits of improving their habits and helping them stay safe during the COVID-19 crisis.

Rawendy et al. [18] stated that learning the Chinese language is becoming increasingly popular due to China's growing economy in the world. In Indonesia, the Chinese language is being taught to children from a young age, though the process can often be arduous and tedious for them. To address this issue, the previously referenced paper proposes gamification and mnemonic methods to help children learn the Chinese language in an engaging and fun way. Gamification is the process of applying game elements to non-game contexts, and mnemonic methods are strategies used to improve memory. Studies conducted using these methods have produced positive results in educational settings. This

game was designed for children aged 6–12 years, and the results of the pre-and post-tests indicate that the game is effective in creating an interest in learning the Chinese language. Ultimately, the paper demonstrates that the developed game succeeded in improving the children's interest in learning the language, which helps in memory improvement as well.

Morimoto et al. [19] mentioned that dementia is a major social problem in Japan that requires early detection and prevention. To measure the progression of dementia, welfare facilities use check tests. However, these tests can be intimidating for elderly people and require regular assessment, which is a burden for medical and care providers. Recently, research has shown that cognitive functions can be measured by focusing on brain functions and eye movements. This paper introduces a new dementia evaluation system that uses a simple puzzle game to measure eye movements, aiming to reduce the burden on medical staff and elderly individuals. Despite COVID-19, the authors conducted a preliminary experiment with healthy subjects, resulting in the collection of eye movement data during the puzzle game.

Furthermore, with the aim of assisting daily activities, Mize et al. [20] stated that students with reading learning disabilities (RLDs) have several issues with their basic reading abilities, including in oral reading fluency. Several previous works considered that issues with a lack of consideration of fluency, comprehension, and word recognition make this work insufficient. Therefore, the authors of this paper proposed a combined approach of using peer-assisted instruction (PAI) and iPad-assisted instruction (IAI) based on visual analysis and effect size calculation to identify the reading fluency of students with reading learning disability (RLD) or dyslexia. They experimented with their proposed approach in iPad devices on four 5th-grade students including males and females of 10–11 years of age. The results show that the proposed combined approach is effective in assessing the oral reading fluency of students with RLD.

da Silva et al. [21] claimed that developing assistive technologies or devices for people with cognitive disabilities to assist their daily activities is challenging as the usability and effectiveness of the developed device depends on several aspects including high cost. Therefore, it is important to develop solutions that meet the specific needs of people with disabilities and that also could be effective for their physical and mental well-being. With these concerns in mind, they proposed and developed a low-cost prototype that could act as assistive technology for the educational activities of adolescents with cerebral palsy (CP). The developed tool was experimented on four participants diagnosed with CP including males and females of 14–19 years of age. Further evaluation for user satisfaction was also performed with the educator through a Quest Version 2.0 questionnaire. The educator's opinion was that the developed prototype is effective in improving skills and improving motor function in people with CP.

Buitrago et al. [22] mentioned that independently sitting, standing, walking, running, and jumping are the most common difficult tasks for children with cerebral palsy. The therapeutic process for these difficulties requires intensive and extended sessions, dedication, and effort. Therefore, they proposed a therapeutic process focusing on SMART objectives (Specific, Measurable, Achievable, Realistic, and Timed) using social assistive robots called NAO robots. The experiment was performed on an 8-year-old boy with dyskinetic cerebral palsy to improve his motor learning with regards to walking. The results show that, with the social robot, it could be possible to improve motor learning and improve the performance of children with dyskinetic cerebral palsy.

Nishiura et al. [23] focused on the support of older people with cognitive impairment and dementia as these are some of the main causes of disabilities among older people. With this aim, they proposed an electric calendar-based assistive technology for older people to improve their cognitive functionality. They experimented with their proposed AT on 27 older adults with or without dementia, where 9 were men and 18 were women, with an age range of 72–94 years.

Pinard et al. [24] claimed that the number of people with traumatic brain injury (TBI) is growing every year. Unexpectedly, to help them during their daily activities, especially for

household work such as cooking, the number of assistive technologies is insufficient. Focusing on this issue, they developed a context-aware assistive technology, namely COOK, for assisting users with cognitive disabilities to help them in meal preparation. Its major focus is on ensuring security and cognitive support with a user-centric design. The developed tool was experimented with in three participants' apartments and brought satisfaction to the users.

Evmenova et al. [25] focused on the increasing number of young adults with intellectual and developmental disabilities (IDD) in recent days. They noted that students with IDD have several issues, including difficulty communicating with others and maintaining self-regulation and positive behaviors, which are important to improve. With this concern in mind, they developed a wearable device as an assistive technology using a smartwatch app and an inclusive design process. The proposed solution was experimented with on 52 students of 18–27 years of age. The results, in both a qualitative and quantitative manner, showed the effectiveness of the proposed solution.

Jacinta Douglas and Christine Bigby [26] mentioned that, in Australia and the USA, at least 5% of people have cognitive impairment that requires support for decision-making. Therefore, they proposed an evidence-based support system for decision-making practice for people with cognitive disabilities to make their own decisions across life domains. This system also supports families, workers, guardians, and health professionals. They also evaluated the system using health professionals, demonstrating the effectiveness of the proposed system.

Kang and Chang [27] claimed that people with intellectual disabilities (ID) experience several difficulties in undertaking independent tasks, especially those involved in daily living, such as personal hygiene. They proposed a game-based therapeutic process or assistive technology using a Kinect V2 sensor to assist students with intellectual disabilities with how to wash their hands by themselves without asking for help from others. The proposed solution was experimented with on four participants and the results showed the overall improvements and effectiveness of the developed tool.

An article by Mihailidis et al. [28] proposed using a computerized device, called the COACH, to assist people with dementia in performing activities of daily living. The device monitors progress and provides reminders using Artificial Intelligence, reducing the need for constant supervision by caregivers. The COACH was tested using a personal computer and video camera to track user behavior and provide prerecorded cues. Preliminary testing showed an efficacy of approximately 95%, with more clinical testing and evaluation ongoing. The device has the potential to increase independence and privacy for people with dementia, as well as reduce caregiver burden.

Luxton [29] discussed the current and potential applications of Artificial Intelligence (AI) in clinical psychology, including in clinical training, treatment, psychological assessment, and decision-making. The article also introduces the concept of an integrated AI-based clinician system. The authors consider the implications of AI technology in the mental health care field, including the potential for job loss among mental health professionals and ethical considerations. Psychologists and other mental health care professionals are seen as having an important role to play in the development, evaluation, and ethical use of AI technologies. Overall, the authors highlight the potential for AI to transform the mental health care field, while acknowledging the need for careful consideration of the ethical and practical implications of these technologies.

Sheri et al. [30] discussed the role of AI and machine learning in diagnosing and preventing diseases, specifically Alzheimer's disease, which is the most common cause of dementia. The proposed solution is an AI-based application called "Memory Stash Alzheimer's Aid," which aims to assist patients in all seven stages of the disease by providing various features that improve their quality of life. The article highlights the limited features and focus of current Alzheimer's applications, making this proposed solution unique in its comprehensive approach. The application will help patients with their daily tasks, and its advanced features will support their needs throughout the various

stages of the disease. Overall, the article emphasizes the importance of AI in healthcare and how it can positively impact the lives of patients with incurable diseases like Alzheimer's.

4. Discussion

We investigated 23 studies in the area of assistive technology for people with cognitive disabilities, addressing several aspects of social and physical skill improvement/development to help people with cognitive disabilities using several technologies, such as Virtual Reality (VR), mobile technologies, robotic technologies, smart technologies, AI assistance tools and chatbots, etc. In recent years, VR has been shown to be a valuable tool in cognitive rehabilitation, assessment, and training. Several studies have investigated the use of VR-based systems for everyday memory assessment, working memory training, and cognitive testing in patients with dementia, stroke, and Major Depressive Disorder. The use of VR allows for the creation of an immersive virtual environment that can replicate physical activities and provide a more ecological way to evaluate cognitive skills. On the other hand, mobile, robotic, and smart applications can be powerful tools for improving memory and cognition, particularly for the elderly. These applications have been used for a variety of purposes, including in helping to manage memory loss, while also providing educational and therapeutic gaming experiences. Through the use of music, gamification, mnemonic methods, and puzzle-based games, engaging and entertaining experiences can be provided. Such applications can provide an alternative form of treatment, with the potential to be more effective than traditional methods (see Table 2).

The articles highlight the importance of developing and implementing more ecologically valid studies and integrating emerging technologies such as Virtual Reality and expert systems to enhance memory rehabilitation efficacy. The potential of Artificial Intelligence to provide substantial improvements in healthcare is discussed, including those directly associated with healthcare and those in the healthcare value chain. Overall, this collection showcases the potential of technology to support healthcare personnel and caregivers, reduce caregiver burden, and increase independence and privacy for people with dementia while contributing to advancements in healthcare interventions.

The articles emphasize the significance of conducting more ecologically valid studies to improve memory rehabilitation efficacy and integrating innovative technologies such as Virtual Reality and expert systems. They showcase the potential of technology to assist healthcare personnel and caregivers in supporting individuals with dementia, reducing caregiver burden, and increasing independence and privacy for patients. These findings contribute to the advancement of healthcare interventions and underscore the crucial role of technology in supporting healthcare professionals and caregivers.

However, all the reviewed studies have several strengths, limitations, and implications that are noteworthy to consider in future research or developments in similar applications. The strengths include early detection, the possibility of performing real-life simulation, lower costs compared to clinical solutions, the possibility of providing treatment with available technologies, the possibility of providing treatment, therapy, and assisting guidelines with entertainment, increased user interest, possible reduced burden of testing, the possibility of motivating people, and the possibility of implementing user-centric designs.

Early detection is related to identifying cognitive decline in patients to the benefit of both the user and physician. An example of this is memory assessment with Virtual Reality-based systems to help to check for any associations between performance and age, performance and years of education, and reaction time and age. Based on the assessment results, it is possible to identify any issue that could previously have caused memory decline.

Table 2. Summary of the investigated studies based on their gaps and facts.

Ref.	Identification of Gaps and Contradictions	Relevant Facts and Theories
[8]	The article states that pharmacological treatments for memory disorders are costly and have adverse effects, but it does not provide any evidence or examples to support this claim. Without supporting information, it is difficult to determine if this is a valid statement or a generalization.	Games have been proposed as a potential intervention for elderly individuals with memory disorders based on their strengths. Playing games requires mental concentration, memory, and quick motor reactions, which can stimulate the brain and potentially help improve memory.
[9]	Limited sample size: The study mentions that the tasks were evaluated on a sample of only 22 healthy participants. While this may be a pilot study, a larger sample size is typically required for more robust and generalizable results. Limited scope of participants: The study focuses on healthy participants, and there is no mention of including individuals with cognitive impairments or specific conditions such as mild cognitive impairment (MCI), Alzheimer's disease, or dementia. Consequently, the generalizability of the results to clinical populations remains uncertain.	The study highlights that VR has the potential to be used in cognitive rehabilitation interventions for diagnostic and training purposes.
[10]	A total of 46 MDD patients and 41 healthy controls (HC) were recruited, but the study does not provide information on the demographic characteristics of the participants (e.g., age or gender) or how they were matched between groups. The article does not discuss the specific population characteristics of the MDD patients included in the study (e.g., severity of depression or comorbidities), making it challenging to assess the external validity of the results.	The article mentions that WMT has been reported to improve EBPM, but its specific effect on EBPM in individuals with MDD is still uncertain.
[11]	The article mentions data collected from 47 participants, but it does not provide information on the characteristics of the participants (e.g., age range, gender distribution, or clinical background). Additional details about the participants would provide a better understanding of the sample and its representativeness.	The article mentions that the data, including behavioral and EEG data (both raw and processed), scripts, and the full task, are available for further investigation. This makes the dataset valuable for researchers interested in studying neural signals during attention cueing, memory encoding, maintenance, and retrieval, as well as those interested in combining VR and EEG.
[12]	The information presented does not provide sufficient details about the characteristics of the participants involved in the studies. It would be useful to know more about the demographic characteristics, such as age range and gender distribution, and any relevant clinical information (e.g., presence of cognitive impairments) of the participants in each study. This information is important to understand the generalizability of the findings and the potential limitations of the studies.	New method: The Virtual Shop is a fully immersive task designed to assess memory in a more ecologically valid manner compared to traditional neuropsychological assessments.

Table 2. *Cont.*

Ref.	Identification of Gaps and Contradictions	Relevant Facts and Theories
[13]	Lack of specific information: The paper mentions the need for utilizing automated techniques in dementia research but does not provide specific details about the automated techniques or their advantages over traditional clinic tests. It would be helpful to have more information on the specific techniques and technologies being referred to.	There is a growing need to utilize automated techniques in dementia research. This is driven by the desire to fully leverage the advantages offered by advanced innovations. Automated techniques have the potential to enhance the efficiency, accessibility, and cost-effectiveness of dementia detection and training methods.
[14]	The study highlights the potential of HMD-VR therapy for stroke patients, but it does not compare the outcomes or acceptance of HMD-VR to traditional therapy approaches. A comparison with established rehabilitation methods would help assess the relative effectiveness and advantages of HMD-VR as a therapeutic tool for stroke patients.	The background highlights that therapy with Virtual Reality (VR) shows potential as an engaging, effective, and cost-effective approach to improving cognitive abilities following a stroke. This suggests that VR therapy may offer advantages over traditional therapy methods and can be a valuable tool in stroke rehabilitation.
[15]	The paper does not mention the duration of the study or whether the treatment's effects were assessed over an extended period. Additionally, it would be valuable to explore the generalizability of the treatment's effectiveness by considering factors such as the severity of stroke, age, and other demographic variables of the participants.	The researchers have developed a computer-based treatment that utilizes visual imagery to help stroke survivors improve their performance in time- and Event-based Prospective Memory tasks.
[16]	This research found that the MT1 app has the potential to become more versatile and automated, allowing for widespread use and ease of access as a memory support tool. However, it is not clear how the app can become more versatile and automated, as specific improvements or features are not mentioned.	The study highlights the use of music—specifically the MT1 composition—and its translation into a mobile application as a memory support tool.
[17]	The paper mentions the aim of targeting users who can benefit from improving their habits and hygiene awareness during the COVID-19 pandemic. However, it does not specify the characteristics or demographics of the intended target audience. Identifying the specific audience, such as age groups, gaming preferences, or specific hygiene concerns, would provide better insight into the intended user base for the prototype.	The paper acknowledges the current rapid growth and impact of the gaming industry, suggesting that it has become one of the most impactful industries globally. This reflects the increasing popularity and influence of gaming as a form of entertainment and interactive media.
[18]	The article mentions that the developed game can help to develop interest in children to learn the Chinese language based on pre-test and post-test results. However, it does not elaborate on the specific outcomes or improvements observed in the test results. Providing more details on the positive results would strengthen the argument and provide a clearer understanding of the game's effectiveness.	The study acknowledges that learning the Chinese language can be difficult for children, which can make the learning process boring for them. This highlights the challenge faced by students in acquiring proficiency in a new language.

Table 2. *Cont.*

Ref.	Identification of Gaps and Contradictions	Relevant Facts and Theories
[19]	The study mentions that many welfare facilities use check tests to measure the progression of dementia, but it does not provide details about these tests. Without further information, it is unclear how these tests are conducted and what aspects of cognitive function they assess.	The paper highlights that the increasing number of dementia patients is a major social problem in Japan. This fact emphasizes the significance and urgency of addressing dementia-related issues, including early detection and prevention.
[20]	The paper does not clarify what the "combined approach" refers to. It is not clear whether the combined approach involves simultaneous implementation of PAI and IAI or if it involves alternating between the two approaches. Additional information is needed to understand the specifics of the combined approach used in the study.	The overall findings of the study showed moderate and positive experimental effects on oral reading fluency. This suggests that the combined PAI and IAI approach had a beneficial impact on the oral reading fluency of the participating students with RLDs.
[21]	The study does not discuss any limitations or challenges encountered during the study. Including information about limitations or challenges faced in the usability evaluation would provide a more comprehensive understanding of the effectiveness and potential areas for improvement of the prototype device.	The concept of assistive technology encompasses various areas of action, including communication, to provide accessible solutions that help individuals overcome daily difficulties. It aims to enhance functional abilities, promote inclusion, and support independent living.
[22]	The article acknowledges the need for more studies to validate the potential of using social robots in therapeutic interventions for children with motor disabilities like cerebral palsy. However, it does not propose any future research directions or highlight specific areas that require further investigation.	The use of new technologies, such as humanoid robots, in therapeutic processes opens up possibilities for developing new strategies and understanding their impact on rehabilitation. The use of formal methodologies, along with multidisciplinary teams, can increase the potential of using social robots to improve cognitive and motor outcomes in children with cerebral palsy. The study observed that the motivation generated by the interaction with the social assistive robot facilitated persistence in walking and the fulfillment of therapeutic objectives.
[23]	The study states that participants showed a significant increase in their total Mini-Mental State Examination (MMSE) scores after the intervention period, but it does not specify if this increase was observed in both groups (first and second intervention group) or only in one of them. Clarification is needed to understand the impact of the electric calendar on cognitive function.	Participants who used the electric calendar showed a significant increase in their total MMSE scores after the intervention period, while there was no significant difference in the group without intervention.
[24]	The article states that COOK is the first cooking assistant in which evidence-based cognitive rehabilitation interventions have been translated into smart technological assistance. However, it does not provide evidence or references to support this claim.	COOK shows promise for rehabilitating clients with cognitive disabilities, enhancing safety in a home environment, and reducing the need for human supervision.

Table 2. *Cont.*

Ref.	Identification of Gaps and Contradictions	Relevant Facts and Theories
[25]	The paper does not provide details about the specific features or functionalities of the wearable technology application designed to support students' learning, participation, and independence. Understanding the specific capabilities of the technology would help evaluate its potential effectiveness.	The findings suggest that wearable technology can support young adults with IDD in inclusive college courses without relying heavily on support staff.
[26]	The study mentions that at least 5% of people in Australia and the USA have cognitive impairment, but it doesn't provide clear information about how cognitive impairment is defined and diagnosed. Without a clear understanding of the criteria used, it becomes difficult to determine the scope and applicability of the research program and framework.	Prevalence of cognitive impairment: The paper states that at least 5% of people in Australia and the USA have cognitive impairment and require support for decision-making. This fact highlights the significance and relevance of developing effective support mechanisms for individuals with cognitive disabilities.
[27]	Lack of information on the Kinect V2 sensor and its application: The paper mentions the use of the Kinect V2 sensor to gamify hand washing, but it does not provide any details about the capabilities or features of the sensor. Additionally, the paper does not explain how the sensor was used or how it contributed to the gamification of hand washing. Without this information, it is difficult to evaluate the appropriateness or effectiveness of the technology in supporting the intervention.	The paper mentions the adoption of a non-concurrent multiple baseline design to demonstrate the relationship between game-based intervention and independent hand washing. This design involves implementing the intervention at different times for each participant, allowing for comparisons and analysis of the intervention's effects across multiple baselines.
[28]	The article suggests that using a computerized device like the COACH might improve the situation for individuals with dementia by reducing the need for continuous caregiver supervision. However, it also acknowledges that the COACH issues prerecorded cues of varying detail, suggesting a form of continuous assistance and monitoring. This contradiction raises questions about the actual level of privacy and independence the device provides, and how it addresses the concerns of the affected individuals becoming embarrassed and agitated.	The article proposes the use of a computerized device, specifically the COACH, to improve the situation for individuals with dementia. The device is intended to monitor progress and provide reminders needed to perform daily tasks. This suggests the application of technology to enhance independence and reduce the need for constant caregiver supervision.
[29]	The study introduces the concept of an integrated AI-based clinician system but does not provide any information or explanation about what this system entails or how it would function. This lack of detail leaves the reader with unanswered questions about the proposed system and its potential benefits or limitations.	The study mentions several AI-assisted activities in clinical psychological practice, including clinical training, treatment, psychological assessment, and clinical decision-making. This indicates that AI can be utilized to support and enhance these areas of practice.
[30]	No mention of ethical considerations: The article discusses the development of an AI-based application for Alzheimer's disease but does not address potential ethical considerations associated with data privacy, consent, or the impact of relying solely on technology for the care and support of individuals with Alzheimer's disease. The ethical implications of developing and using AI in healthcare should be acknowledged and discussed.	The article suggests that the proposed AI-based application has the potential to improve the quality of life for individuals with Alzheimer's disease by providing support and assistance throughout all stages of the disease.

Performing real-life simulations is a great way to improve an individual's ability to perform a particular task. For example, in training patients with Major Depressive Disorder (MDD), real-life simulation is the best approach. Applied examples could include simulated working training scenarios such as supermarket shopping that help users to practice and improve their ability to independently shop for themselves.

Most of the solutions discussed are more cost-effective than clinical devices or procedures (e.g., MRI scans). An automated technique could be less costly compared to traditional clinic tests and more effective. For example, a 3D virtual environment-based serious game to assess dementia patients provides immersive virtual conditions with extra advantages for psychological tests, as well as providing an efficient and cost-effective way of testing dementia patients. The proposed game can provide more accurate results than traditional methods.

These automated assistive technologies allow us to implement or ensure guidance with available technologies or devices such as AR/VR technologies, mobile phones, iPads, laptops, and wearable technologies such as smart watches, smart calendars, etc. For example, for stroke patients, it is possible to improve their cybersickness and performance in memory span and speed tasks with HMD-VR technologies, especially in older adults, even without prior knowledge or experience. Moreover, the majority of applications use mobile phones, iPads, and laptops, which are cheap and easily accessible to users and easy to maintain during their daily activities.

In terms of entertainment and increased user interest, several games have been developed to train people with cognitive disabilities in an entertaining manner. For example, a mobile application, namely the MTI app, was developed, composed of music to aid students in memorizing semantic declarative facts. This application is effective for the learners due to its entertainment facilities, and helps to increase their interest in using assistive technologies in the future.

For reducing the burden of testing, in general, adaptive training requires significant clinical input and requires variables to be strictly controlled, which is difficult to control for human investigators and increases the burden on the patient. With computer-aided programs or applications, it is possible to shift this from a manual training to a virtual training process. For example, Prospective Memory (PM) is an important type of memory for everyday life; however, it is often impaired in stroke survivors. Therefore, it is possible to employ computer-based treatment using visual imagery to teach PM tasks in a better way, which could reduce the burden on the user.

Automated applications or assistive technologies have the potential to motivate people with cognitive disabilities to learn new things. For example, gamification is helpful in teaching Chinese to children with cognitive disabilities at an early age and helping to improve their memory development, thereby also increasing the satisfaction and motivation of their parents.

These solutions allow the implementation of user-centric design, which is an emerging need, especially for people with cognitive disabilities, for improving their understanding during the therapeutic/treatment/assisting process. For example, an assistive application for guiding cooking procedures has a user-centric design that is validated by the user and expert requirements and suggestions. The user-centric design improves its effectiveness.

However, several limitations have been observed, such as ambiguity in trail environment, small study samples, risk of simulator sickness, language barriers, lack of validation processes, disability-specific solutions, and device transparency. The majority of the applications display ambiguities in the trial environment, such as whether they could be possible to implement in clinical environments or the home environment. Therefore, transparency is important for implementing these applications widely in multiple environments.

While there are several positive aspects highlighted in the articles, it is important to acknowledge their further limitations. Specifically, the articles discussing the use of VR in cognitive rehabilitation fail to address the accessibility and affordability of these technologies, which may prevent certain populations from benefiting from them. Additionally,

ethical concerns related to the use of AI assistance tools in cognitive rehabilitation, such as privacy issues and the potential for these technologies to replace human caregivers, are not adequately addressed in the articles.

In order to validate the developed applications, the experimentation process was performed with consideration of the small number of samples or participants that might reduce the effectiveness in the future in terms of a large number of participants. Furthermore, AR/VR-based applications have a high risk of simulator sickness during experimentation due to the strong grade of immersion. This aspect might reduce the effectiveness of the developed application.

Language barrier is another limitation as most of the applications use the English language. For older aged people or children, it is burdensome if there is no option for language translation for the specific group of users. Moreover, developed applications are specifically disability-oriented, which might reduce the effectiveness for other disability types with cognitive barriers.

In validating applications, consideration of only users is not helpful every time. Therefore, professionals are advised to validate applications to justify their effectiveness and authenticity. Most importantly, device transparency is significant as, due to device specifications, many users might not use particular applications, which renders them ineffective for both application developers and users.

Furthermore, it is interesting to mention that the majority of the selected or reviewed studies have focused on VR technology to implement the developed assistive technologies. The number of applications considering mobile technologies and smart technologies such as smartwatches is not significant. Though VR applications have the potential for smooth user assistance, sometimes they might not be convenient for the user as they are a bit costly and time-consuming to learn how to operate. As mobile technologies and smart technologies are prominent and popular among people, future development should consider these issues and develop more applications by adopting these technologies. Moreover, most of the selected studies developed their applications considering a particular group of people. This might not be effective and reduce the effectiveness of the developed solution. For any type of development, the audience should not face any barrier to accessing the application. Therefore, future developed assistive technologies or applications should consider this fact and develop solutions for every group of people with the targeted disability.

However, to represent the insights of our review work, we compared our work to other existing works. In total, we have found five literature review works focusing on four specific disabilities in the area of cognitive aspects, such as impaired cognition, dementia, autism, and Alzheimer's disease (AD). For example, Brandt et al. [31] presented a review work considering information and communication technology-based assistive technology. The presented knowledge is helpful in providing an understanding of the currently developed assistive technologies for people with impaired cognition. Lee-Cheong et al. [3] and Goodman-Casanova et al. [32] presented detailed reviews of newly developed assistive technologies for people having dementia problems. Furthermore, Desideri et al. [33] and Christine K. Syriopoulou-Delli & Eleni Gkiolnta [34] presented studies focusing on the training processes of daily-life-supporting assistive technologies for people including children with autism. In addition, Yousaf et al. [35] focused on mobile-based assistive technologies for people with Alzheimer's disease (AD). In spite of the importance of these review studies, they focused on a particular disability group and particular target user; in future, applications or assistive technologies for other cognitive disorders and a wide array of target users should be focused on. To overcome this limitation, in this work, our major focus is to consider assistive technologies for cognitive aspects including a wide array of disabilities, and target users that could be beneficial for a wide group of people who are working to develop such solutions in the future. This can be seen in the Figure 3 diagram, which illustrates a summary of the paper.

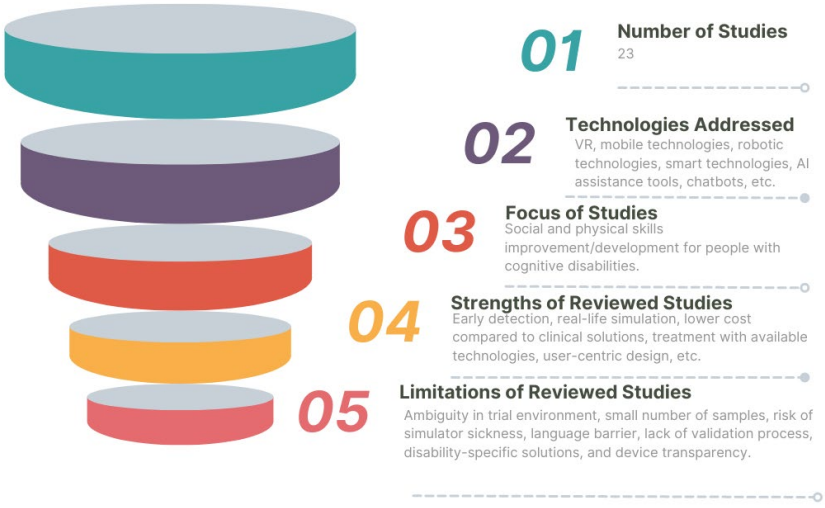

Figure 3. Funnel diagram illustrating a summary of the paper.

Moreover, according to our observations, the investigated applications have effectiveness, though they are not free from limitations. In future developments, the addressed limitations should be incorporated to improve their effectiveness for a wide array of people. In addition, development should also focus on other disability types for the improvement of their specific disabilities.

5. Further Development Opportunities

As technology continues to advance at a rapid pace, there are a remarkable array of assistive technologies being developed to aid individuals with memory disorders. These innovative solutions have the potential to greatly improve the quality of life for those facing challenges related to memory impairments. In our current paper, we have begun to explore this fascinating landscape, analyzing existing research and examining the effectiveness of various assistive technologies. However, our ambition extends far beyond the scope of our initial investigation. Moving forward, we have a comprehensive plan to expand and enhance our review in several key areas.

Firstly, we aim to incorporate additional papers from diverse technology fields that intersect with the realm of memory assistance. This entails exploring cognitive training software, web-based applications, mobile apps, wearable devices, and other cutting-edge technologies that have shown potential in aiding memory-related difficulties. By including a broader range of sources, we can gather a more holistic understanding of the available options and identify promising avenues for further exploration. Moreover, our future endeavors involve delving into various types of memory disorders to assess the specific challenges and requirements associated with each condition. Conditions such as Amnesia, Huntington's disease, Parkinson's disease, and Traumatic Brain Injury present distinct sets of difficulties and necessitate tailored approaches. By exploring the latest research and advancements in assistive technologies targeted at these specific disorders, we can provide valuable insights and recommendations for individuals facing these challenges. Furthermore, we recognize the importance of considering the diverse demographic characteristics of the user population. In our expanded review, we intend to address the needs of individuals across different ages, genders, and backgrounds. By taking into account factors such as age-related memory decline, gender-specific considerations, and cultural influences, we can better understand the unique requirements and preferences of individuals with memory disorders, leading to more effective and inclusive assistive solutions. In addition to our focus on assistive technologies, we acknowledge the growing significance of Artificial Intelligence (AI) in this field. While we briefly mentioned AI in our initial article, we recognize the need to delve deeper into its applications and potential contributions to memory assistance. As such, our future plan involves supplementing our review with a dedicated

exploration of AI techniques, including machine learning, natural language processing, and computer vision. This will enable us to uncover the ways in which AI can enhance the development and implementation of assistive technologies for memory disorders, paving the way for more advanced and personalized interventions. By expanding our review in these crucial areas, we aim to contribute to the growing body of knowledge surrounding assistive technologies for memory disorders.

Our comprehensive approach seeks to provide a thorough assessment of available technologies, highlight emerging trends, and offer insights into the potential of AI, all while ensuring inclusivity and addressing the diverse needs of individuals with memory disorders. Through our efforts, we aspire to make a positive impact on the lives of those affected by memory impairments, fostering independence, and enhancing their overall well-being.

Certainly, there are other resources available in this field [36–39]. However, our research stands out due to its inclusion of more recent articles in the field and its broader coverage of technologies, including AI, mobile, wearable technology, tablets, and more.

6. Conclusions

This paper intends to identify several assistive technologies or applications for people with cognitive disabilities and summarize their strengths and limitations to understand the effectiveness of the developed application. The majority of the studies demonstrated impressive results, despite several limitations that have been noted as shown in Table 1. The findings of this study demonstrate that the integration of IT and assistive technology has the potential to make a significant positive impact on building a sustainable society.

To conclude, we can state the following:

- IT solutions like Virtual Reality, mobile technology, and wearable technology can be used as a home-based alternative therapy.
- These can be used as a new methodology to develop valid tests that assess memory functions.
- Additional to the previous statement, we can infer that these are more cost efficient (lower cost than clinical devices).
- AI can increase the efficiency and accuracy of diagnosis and treatment.

The outcomes obtained from this paper might be useful for professionals, therapists, psychologists, parents, innovators, and other associated people with cognitive disabilities to understand and further examine each procedure and their functionalities. This work might also be useful for the stakeholders to understand the potentiality of the selected applications for promoting and enhancing the use of these technologies or applications. However, further studies are necessary to evaluate their effectiveness and present a comparative result.

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