Artificial Intelligence Review (2025) 58:78
https://doi.org/10.1007/s10462-024-11084-8

Systematic review of recent years: machine learning-based interactive therapy for people suffering from dementia

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Accepted: 23 December 2024 / Published online: 6 January 2025

Abstract
Medical advances over the last century have significantly extended life expectancy. Today, the world's population is quite old, and will become even older in the years to come. Diseases that particularly concern the elderly are therefore more frequent, and dementia is one of them. This condition mainly affects the elderly and cannot be cured today. However, people suffering from dementia do require care, and this entails significant costs for our society. Machine learning could be useful in a context where it is difficult to find medical staff and where cost reduction is a priority. In recent years, research has been conducted to find ways of treating dementia with machine learning-based therapies in which the patient can actively participate. In this paper, a systematic literature review of these therapies is conducted: (a) paper metadata is analysed, (b) dataset characteristics are examined, (c) therapy types are compared, (d) suggested architectures are considered, (e) therapy performance is reviewed, (f) usability is discussed, and g) ethical considerations are taken into account. Twenty-three papers were selected in which various types of therapy were suggested for use with cell phones, computers, robots, or virtual reality. The results of the usability tests were very positive, both in terms of cognitive faculties evolution and patient satisfaction.

Keywords Dementia · Machine learning · Therapy · Artificial intelligence

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1 Introduction

Currently, more than 55 million people live with dementia worldwide and this number increases nearly by 10 million every year (World Health Organization 2023). Moreover, dementia is the seventh leading cause of death as well as one of the major reasons of dependency among older adults (World Health Organization 2023). By 2030, a third of the population of Western Europe is expected to be over 60 years old (Abdi et al. 2018). Dementia is therefore becoming a global health issue. The World Health Organization has thus launched a global action plan against dementia, and points to the need for urgent action to achieve the targets set by the plan, which runs until 2025 (World Health Organization 2021). In fact, research should be encouraged more intensively to find solutions that would enable to prevent, delay, and mitigate the consequences of dementia.

Dementia can be defined as a variety of diseases and injuries which affect the brain (World Health Organization 2023). Over time, cognitive abilities such as memory, reasoning, and speech gradually decline. The most common form of dementia is Alzheimer's disease and is estimated to contribute to 60–70% of cases (World Health Organization 2023). Another condition is mild cognitive impairment and is an intermediate stage between a cognitively normal brain and severe dementia as Alzheimer's disease (Petersen 2016). The current systematic literature review covers all types of dementia, from mild cognitive impairment to Alzheimer's disease.

Dementia has a major impact on the lives of those affected. In addition to memory loss, sudden mood swings, confusion, loss of speech, and difficulties with walking and balance can occur (Aggarwal et al. 2022). These consequences of dementia can lead to the social exclusion of those affected because they may struggle to communicate with others or feel embarrassed to be in public. This results in agitation, anxiety, and depression (Aggarwal et al. 2022). Apart from patients, family caregivers are often needed and carry a significant burden (Brodaty and Donkin 2022).

Today, medication cannot cure dementia (Alzheimer's Association 2024). However, non-pharmaceutical approaches can be implemented to improve quality of life and well-being, and eventually slow the progression of the disease. These approaches are multidisciplinary, involving cognitive, physical, and social interventions. Cognitive training consists at trying to enhance memory and attention through therapies like exercises and games. The goal of physical therapy is that patients stay active, which helps to maintain the overall physical health. Social interventions consist of taking part in activities and social interactions that enhance emotional well-being (World Health Organization 2023). There is already evidence of the effectiveness of these non-pharmaceutical interventions (Cooper et al. 2012).

Dementia entails significant costs, including medical expenses such as hospitalization and home care. In more advanced cases, placement in a nursing home or other specialized facility can increase costs even more. The total cost for long-term and hospice care for dementia patients are projected to increase to nearly $1 trillion in 2050 (Alzheimer's Association n.d.). These expenses result in dementia being one of the most costly diseases in the world (Wimo et al. 2023). This underlines the urgency of finding solutions to treat dementia effectively and inexpensively.

In recent years, there have been huge improvements in the field of machine learning. A lot of research has focused on dementia detection and classification (Li et al. 2022; Lu and Gurram 2023; Luz et al. 2023; Hanai et al. 2022; Zheng et al. 2022). However, only

little research focused on how dementia could be treated using machine learning and non-pharmaceutical therapies. Systematic literature reviews already exist for detection and classification (Shi et al. 2023; Yang et al. 2022a; Shanmugavadivel et al. 2023) but no recent one for therapy-based approaches could be identified. The goal of this systematic literature review is to close this gap, following the Preferred Reporting Items for Systematic Reviews and Meta-analyses guideline (PRISMA 2020). Moreover, the aim is to encourage research in machine learning-based interactive therapies for dementia.

This systematic literature review is structured as follows: in Sect. 2, research papers related to our literature review are outlined. The used procedure to conduct the review as well as the research questions are described in Sect. 3. Next, Sect. 4 presents the analysis of the selected papers in relation to the research questions. Thereafter, Sect. 5 provides an interpretation of the results and suggestions for future research. Finally, Sect. 6 summarizes the key findings and future directions, and outlines the limitations of the review process.

2 Related work

This section presents recent review articles on machine learning applications in dementia. The selected review articles are discussed briefly and compared with our work. Finally, the commonly used machine learning techniques in dementia therapy identified in related works are described.

A number of review articles have been published on diagnosis and classification with machine learning over the last few years. A review published in 2020 (Graham et al. 2020) focuses on papers that use medical data such as socio-demographic information, medical images, clinical assessments, or genomes to predict or detect cognitive decline. A further review (Kumar et al. 2021) deals with papers that use data derived from electronic health records. Another review (Chintalapudi et al. 2022) focuses solely on papers using magnetic resonance imaging (MRI) and artificial intelligence to diagnose dementia. Alzheimer's disease classification using speech and language data is reviewed in a further article (Vigo et al. 2022). Such a classification could in fact take place pretty easily: at a low cost and without any invasive procedure. A further review paper (Yang et al. 2022b) also discusses speech analysis to detect Alzheimer's disease but focusing on deep learning techniques. All of these review papers on diagnosis and classification with machine learning indicated great potential for the future. In contrast to these several reviews, our review focuses on machine learning-based therapies and not on detection nor classification.

Two review papers (Tautan et al. 2021; Fabrizio et al. 2021) discussed the possible applications of artificial intelligence in dementia, namely in diagnosis, monitoring, and treatment. Machine learning-based methods to measure the effectiveness of treatment or to discover new drugs are addressed in the two papers. The findings of these studies show great potential, but underline the need for larger-scale studies and more robust validation. Some challenges, including ethics and data privacy are outlined and should be considered for deployment. However, no machine learning-based therapies as such are addressed. This is the gap we aim to close with our review.

One paper (Bang et al. 2023) reviewed mobile applications for cognitive training while another paper (Russo et al. 2019) reviewed dialog systems and conversational agents for dementia patients. A further paper (Gutiérrez-Pérez et al. 2023) reviewed serious games for

older adults. The results of the reviews showed a promising effect on dementia, but more comprehensive validation tests are still lacking. Although these reviews are relevant in the field of dementia, the use of machine learning was not part of the paper selection criteria. These reviews do, however, include some interesting papers, and those using machine learning techniques and fulfilling our criteria will be included in the present review.

Two reviews published in 2020 (Gochoo et al. 2020; Vogan et al. 2020) focused on robots powered by artificial intelligence. Both papers outlined the promising use of artificial intelligence combined with robotics for cognitive training. However, research is still needed to be able to validate the effectiveness of these therapies. Some concerns, namely ethics, costs, and accessibility need to be addressed before deploying these interventions. These reviews targeted specifically artificial intelligence-based robots, while our review includes any machine learning-based therapy system that involves direct interaction with the patient.

These related works have led to the identification of certain machine learning techniques often used in dementia therapy. A wide variety of techniques are namely employed, including reinforcement learning, natural language processing, and more advanced techniques such as deep learning. Reinforcement learning is often used for its ability to adapt to the faculties of patients and in games. Regarding natural language processing, it targets communication with patients, whether integrated into a robot or not, in written or spoken conversation. Other techniques such as deep learning are also commonly used, for example in robots or for virtual reality. This enumeration of machine learning techniques is not exhaustive, and only presents the techniques most frequently encountered when analyzing existing related works. It aims to provide the reader with an overview of machine learning techniques frequently used in dementia therapy.

3 Methods

This section discusses the methods used to carry out the literature review. The employed methodology is outlined in Subsect. 3.1, followed by the research questions guiding the review in Subsect. 3.2. The selection of databases is explained in Subsect. 3.3, while the research query is discussed in Subsect. 3.4. Next, the inclusion and exclusion criteria used in the selection process are explained in Subsect. 3.5. Subsequently, the selection process is shown in further detail, namely with the help of a flow diagram in Subsect. 3.6.

3.1 Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-analyses guideline (PRISMA 2020) was used to conduct the present systematic review. PRISMA is a widely accepted guideline that provides tools like a checklist and flow diagrams. The main goal of this approach is to enhance the quality and reliability of systematic reviews and meta-analyses. There is no registration number associated with the present review paper.

3.2 Research questions

The present systematic literature review is guided by research questions (RQ) classified into seven categories:

- Metadata_RQ: metadata information about papers
  - Metadata_RQ1: Does the publication year of the paper reflect the development status of machine learning-based dementia therapies?
  - Metadata_RQ2: Is it possible to identify research trends in certain regions of the world from the publishing countries?
- Dataset_RQ: dataset characteristics
  - Dataset_RQ1: Which dataset size is optimal for machine learning-based dementia therapies?
  - Dataset_RQ2: Does the type of data used reflect which are the most pertinent for applications in dementia?
  - Dataset_RQ3: Do the data sources used show the state of data availability in the field of dementia?
- Therapy_RQ: type of therapy
  - Therapy_RQ1: Do the therapies target different types of dementia?
  - Therapy_RQ2: Can the different underlying therapy types be categorized?
- Arch_RQ: architecture of the solutions
  - Arch_RQ1: Does the choice of machine learning techniques reflect the current trends in the field?
  - Arch_RQ2: Is dementia assessment or tracking provided in all therapies?
- Perf_Eval_RQ: performance evaluation
  - Perf_Eval_RQ1: Which model performed best?
  - Perf_Eval_RQ2: What is the current state of performance against dementia progression?
  - Perf_Eval_RQ3: What are the future directions in this field for developing innovative therapies?
- Usability_RQ: usability of the therapy
  - Usability_RQ1: How does the language influence therapy?
  - Usability_RQ2: On which medium (mobile application, robot, etc.) are the therapies offered?
  - Usability_RQ3: Do the patients accept well the available therapies?
  - Usability_RQ4: How autonomous are patients in performing the therapies?
- Ethics_RQ: ethical considerations

– Ethics_RQ1: Which influence had ethical considerations in the selected papers?Research questions will be referred to by their identifiers in the following sections.

3.3 Databases

Papers from 2019 to September 2024 have been taken into consideration. This period of about five years was chosen because three review papers were already published in 2019 and 2020. One review (Russo et al. 2019) already addressed dialog systems and conversational agents against dementia, while two papers (Gochoo et al. 2020; Vogan et al. 2020) focused on therapy with AI-robots. In addition, this short period will enable us to retrieve the most recent advances in machine learning-based therapies, given the significant developments in machine learning in the last few years.

The following databases were queried to retrieve papers:

- ACM Digital Library (ACM Digital Library n.d.)
- IEEE Xplore (IEEE n.d.-b)
- ACL Anthology (ACL Anthology n.d.-a)
- PubMed (National Library of Medicine n.d.)
- Springer Link (Springer Link n.d.)
- Google Scholar (Google Scholar n.d.)ACM Digital Library (ACM Digital Library n.d.) and IEEE Xplore (IEEE n.d.-b) were selected for the reliability of their papers on machine learning applications. ACL Anthology (ACL Anthology n.d.-a) was chosen for its numerous papers on natural language processing, a field of machine learning. PubMed (National Library of Medicine n.d.) is the leading database in the biomedical field and offers numerous papers on machine learning applications in the medical field. The Springer Link database (Springer Link n.d.) was also included for its rich collection of peer-reviewed papers. Finally, Google Scholar (Google Scholar n.d.) was selected for its quality of aggregation of sources to ensure that all relevant papers were included, and to access grey literature.

3.4 Research query

To create the research query, the main concepts were first identified. Then, synonyms were derived to capture all existing papers relevant to the topic. Table 1 shows the identified concepts with their respective synonyms and query. As a large number of articles dealing with diagnosis, detection, or classification were retrieved, a NOT clause was added to keep the results relevant. It was manually checked that the NOT clause did not exclude any relevant papers.

Boolean AND operators were then used to link the concepts, resulting in the following research query:

(NLP OR Natural Language Processing OR text mining OR Machine Learning OR AI OR artificial intelligence) AND (mental degenerative OR neurodegenerative OR Alzheimer OR dementia OR cognitive impairment) AND (therapy OR treatment OR cognitive training OR reminiscence therapy) NOT (diagnosis OR detection OR classification)

Table 1 Search query terms

Concept	Synonyms	Query
Machine Learning	NLP, Natural Language Processing, text mining, AI, artificial intelligence	NLP OR Natural Language Processing OR text mining OR Machine Learning OR AI OR artificial intelligence
Dementia	mental degenerative, neurodegenerative, Alzheimer, cognitive impairment	mental degenerative OR neurodegenerative OR Alzheimer OR dementia OR cognitive impairment
Therapy	treatment, cognitive training, reminiscence therapy	therapy OR treatment OR cognitive training OR reminiscence therapy
NOT diagnosis	NOT detection, NOT classification	NOT (diagnosis OR detection OR classification)

Table 2 Inclusion and exclusion criteria

Criteria	Decision
The predefined keywords appear in the title, keywords, or abstract section of the paper	Inclusion
The paper is part of the grey literature	Inclusion
Duplicate papers	Exclusion
The paper refers to technologies that have no interaction with the patient (e.g. MRI, body fluid analysis, etc.)	Exclusion
The paper was published before 2019	Exclusion

All database results from this query were taken into account, with the exception of Google Scholar, where only the first 100 papers were considered due to the high number of results, and to the mainly cross-checking purpose of this database. Further results in a short range were also manually checked to ensure that no relevant paper was ranked further than the top 100.

3.5 Inclusion and exclusion criteria

Table 2 shows the inclusion and exclusion criteria that have been defined in advance for use in the paper selection process.

For a paper to be included, the words defined in the research query must appear in the title, keywords, or abstract of the papers. Grey literature is considered because it allows a wider range of perspectives, including unpublished studies and other documents that may contain information of interest to the review. Duplicates are excluded from the review. The focus of this systematic literature review is on interactive therapies in which the patient can actively participate. As some papers dealt with radiological or body fluid analysis, these were excluded.

3.6 PRISMA flow diagram

Figure 1 shows the flow diagram that illustrates the identification of papers via databases and the screening process leading to the selected papers.

The identification and screening processes were carried out between March and October 2024. During the identification process, all papers resulting from the search query were

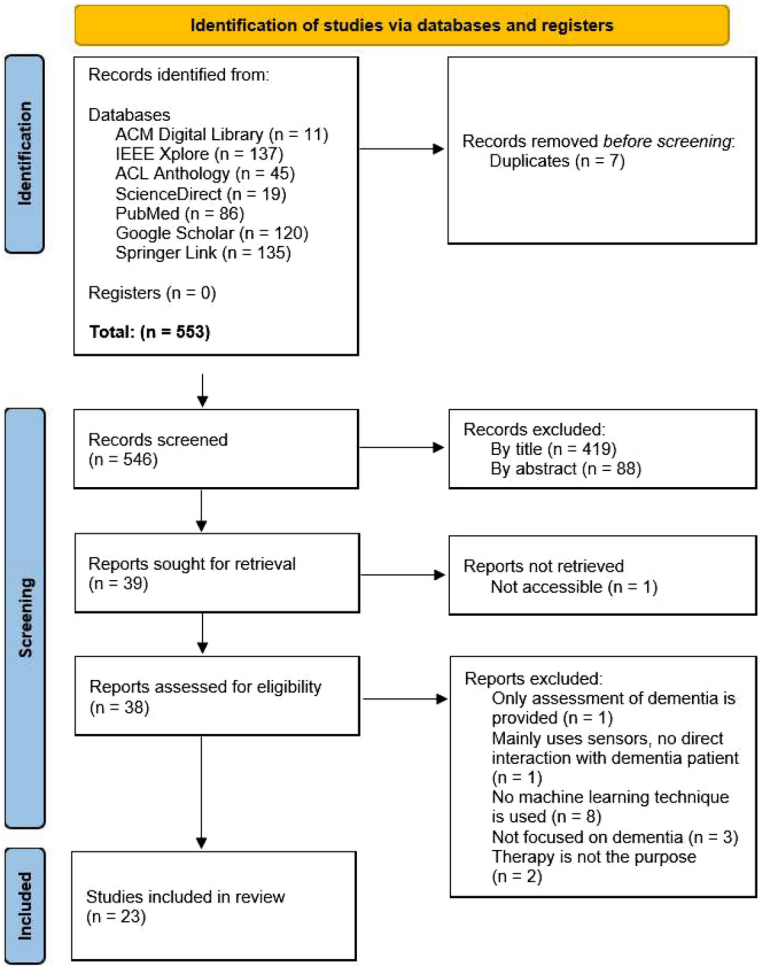

Fig. 1 PRISMA flow diagram

taken into consideration. The screening phase involved first the manual analysis of the paper titles which resulted in the exclusion of 419 papers. Then, the abstracts were manually analyzed which led to the exclusion of 88 further papers. Afterwards, 38 papers remained to be analyzed manually in their entirety. A further 15 papers were finally excluded as they did not meet the defined criteria. In the end, 23 papers were included in the systematic literature review. One author did the critical appraisal, and a more senior author reviewed the choices. The authors worked independently, but they consulted each other about edge cases. The exact reason for each excluded paper can be found in the Excel file in the supplementary material. The most frequent reason was that only detection or prediction was addressed and not therapy. Other common reasons were that no machine learning technique was used or that dementia was not targeted in particular.

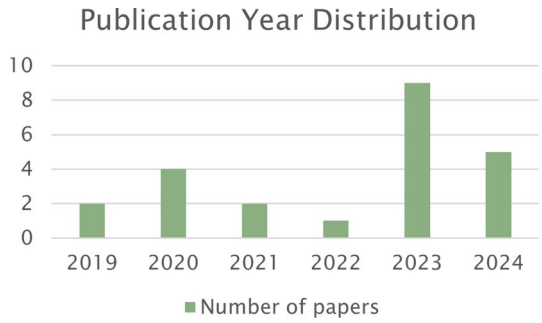

Fig. 2 Publication year histogram

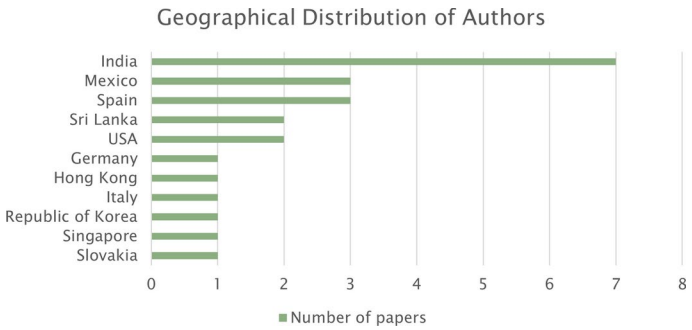

Fig. 3 Geographical distribution of authors

4 Results

In this section, the selected papers are analyzed according to the research questions defined in Subsect. 3.2. First, the metadata questions are discussed in Subsect. 4.1. Next, the dataset questions are addressed in Subsect. 4.2, followed by the therapy questions in Subsect. 4.3. The architecture of the selected papers is then analyzed in Subsect. 4.4, and the performance of the therapies is addressed in Subsect. 4.5. The usability of the suggested therapies is evaluated in Subsect. 4.6, while the ethical questions are discussed in Subsect. 4.7. The glossary in Sect. 7 provides definitions of the machine learning terminology used in this section.

4.1 Metadata questions

The papers considered are those between 2019 and September 2024. Figure 2 shows the distribution of the publication years of the papers (Metadata_RQ1). The number of papers published in 2023 and 2024 is higher compared to previous years. This indicates a growing interest in the subject, which could be related to the recent rapid development of machine learning. Another factor could be the global action plan against dementia launched by the World Health Organization and which lasts from 2017 to 2025 (World Health Organization 2017). One of its main focus is in fact the development of effective therapies.

Figure 3 shows the distribution of the geographic locations of the authors (Metadata_RQ2). The country of the university or organization to which the author is affiliated is considered. If the authors of a paper have different geographic locations, the majority country

is taken into consideration. This was the case for only two papers (Ronquillo et al. 2020; Sheba et al. 2023).

India is the most frequent geographical location among authors. More generally, Asia is the continent that published the most papers. India has in fact a national strategy (NITI Aayog 2018) for artificial intelligence, with healthcare as one of its targets. Some potential use cases in healthcare are mentioned, namely end of life care, treatment, and diagnosis. Spain also has a national strategy on artificial intelligence (Gobierno de Espana 2020), in which great potential for applications in healthcare is described. The Singapore national artificial intelligence strategy (Government of the Republic of Singapore 2023) shortly mentions healthcare as an application, while the USA have a dedicated national plan to address Alzheimer's disease (U.S. Department of Health and Human Services 2023) in which artificial intelligence approaches are promoted. These country-level strategies influence research and might contribute to the number of papers published. In addition, the Asian Pacific region is projected to have 71 million cases of dementia in 2050, compared with 135 million worldwide (Alzheimer's Disease International 2014). The high number of dementia cases and national artificial intelligence strategies in Asia may therefore contribute to the explanation. Due to the small sample size, the explanations of the country distribution should be considered preliminary. Further research and larger studies are necessary to further investigate this matter.

4.2 Dataset questions

Only a few papers mentioned the use of datasets. In fact, many papers used reinforcement learning with some initial rules or subscribed to machine learning paid services. However, the dataset questions are still discussed for the eight papers (Carós et al. 2020; Konapur et al. 2021; Maroto-Gémez et al. 2022; Jiang et al. 2023; Rathnayaka et al. 2021; Sheba et al. 2023; Abirami et al. 2024; Sharma et al. 2024) that use datasets. Table 3 shows the dataset size (Dataset_RQ1), data type (Dataset_RQ2), and data sources (Dataset_RQ3) used in the eight papers. The most frequently used data type is text. Regarding the size of the dataset, it is rather small on average. This is certainly due to the non-existence of suitable open-source datasets as mentioned in two papers (Carós et al. 2020; Jiang et al. 2023). Most papers could not use a single public data source. In fact, data is retrieved from the Internet or collected via a survey, and then processed to make it usable. This underlines the need for more appropriate datasets to encourage research in this area.

4.3 Therapy questions

There are several types of dementia, ranging from mild cognitive impairment to Alzheimer's disease. Figure 4 shows the distribution of addressed dementia types (Therapy_RQ1). Most of the studied papers targeted dementia in general. Four papers (Maroto-Gémez et al. 2022; Jiang et al. 2023; Sheba et al. 2023; Abirami et al. 2024), addressed a more general disorder, namely cognitive impairment. Alzheimer's disease, the most common form of dementia, was targeted by four papers (Joypriyanka and Surendran 2023a; Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020; Llorente et al. 2024). Some papers (Konapur et al. 2021; Maroto-Gémez et al. 2022; Llorente et al. 2024; Sharma et al. 2024) also addressed more than just dementia or cognitive impairment; they

Table 3 Dataset characteristics

Paper	Dataset Size	Data Type	Data Source
Carós et al. 2020	5 000 records	Images and text (5 text questions for each image)	Images: MS COCO (Microsoft 2014), Bing (Microsoft n.d.) and Flickr (Flickr n.d.), Text: PersonaChat (kaggle n.d.-a) and Cornell Movie (Danescu-Niculescu-Mizil n.d.)
Konapur et al. 2021	1 376 records	Text	Online forums (Counsel-Chat n.d.; Reddit n.d.)
Maroto-Gómez et al. 2022	473 records	Text	Online survey
Jiang et al. 2023	2 643 records	Text	Collected and created via cognitive stimulation therapy videos and a book
Rathnayaka et al. 2021	Unspecified	Text	Survey
Sheba et al. 2023	Unspecified	Motion data	Self-collected
Abirami et al. 2024	Unspecified	Images	Self-collected
	Unspecified	Neuro-develop-mental data	Sourced from research institutions and healthcare data repositories
Sharma et al. 2024	36 000 records	Labeled images	Jonathan Oheix image dataset (kaggle n.d.-b)
	162 980 records	Text	Twitter dataset by Tanul Singh (kaggle n.d.-c)

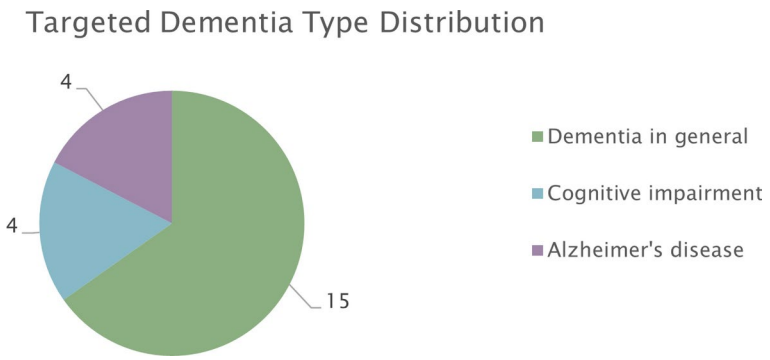

Fig. 4 Targeted dementia type distribution

also targeted other disorders or suggested therapies that can also be offered for physical rehabilitation, entertainment sessions, or mental well-being improvement.

Figure 5 shows the distribution of therapy types (Therapy_RQ2). Most papers suggested therapy through serious games. These are games designed primarily not for entertainment,

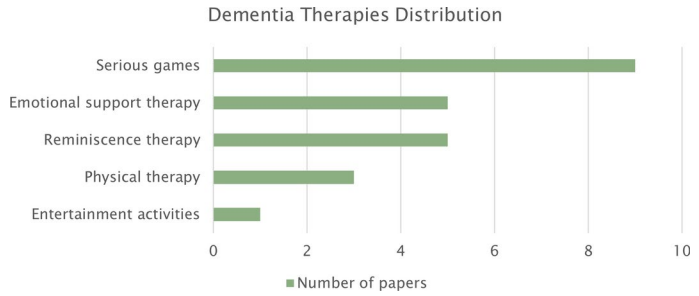

Fig. 5 Dementia therapies distribution

but for other purposes, such as education and training. In dementia therapy, these games are designed to improve or maintain the cognitive functions of patients. The following serious games were proposed in the papers: chess (Joypriyanka and Surendran 2023c, d), checkers (Joypriyanka and Surendran 2023a, b), a farming game (Eun et al. 2023) and combinations of multiple games (Upadhyay 2023; Rathnayaka et al. 2021; Llorente et al. 2024; Abirami et al. 2024). The only one that also exercises the physical abilities of patients was the farming game (Eun et al. 2023) that uses virtual reality.

A common type of therapy among studied papers was emotional support therapy. A paper (Ronquillo et al. 2020) proposed an augmented reality application in which dementia patients can interact with multimedia content. The aim is to detect the emotional state of patients and propose multimedia content according to their tastes, trying to transform the patient's negative emotional state into a positive one. Another paper (Konapur et al. 2021) suggested a chatbot to identify and help users relieve mental stress, in the same way a therapist would. In addition to the chatbot, relaxation techniques are provided too. A further paper (Hruška et al. 2020) proposed a robot to help dementia patients express their true feelings. The emotions of the patient were then analyzed with a camera. Another studied paper (Jiang et al. 2023) suggested a dialog system that provides emotional support to dementia patients. The emotions of the patients are recognized through their responses and the conversation is adapted accordingly. A music recommendation system was suggested by another paper (Sharma et al. 2024). The goal is to detect the emotion of the patient using a camera and a microphone, and then offer music or audio recommendations according to the current emotional profile.

Reminiscence therapy was also pretty common among the studied papers. It consists in stimulating the memory of patients using their own memories. A paper (Carós et al. 2020) proposed a dialog system that is used to ask patients questions based on pictures of their lives. Two papers (Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020) written by the same authors suggest a conversational system in which the patient can have an vocal conversation with the system. A further paper (Leo et al. 2019) proposes to collect patient's memories and organize them into a map such that memories are linked together. The patient can then browse through the map, or communicate with voice or text with the system. The combination of reminiscence therapy with virtual reality is suggested by another paper (Wang and Zhang 2024). The user can describe a memory verbally or through written text, and artificial intelligence is used to create a whole virtual

reality world based on the memory description. The aim is to improve the quality of life of patients by reminding them of happy memories.

Three papers targeted physical therapy. One paper (Kariyawasam et al. 2023) aims to offer short sessions of physical activity to improve the cognitive performance and overall quality of life of patients. Another paper (Sheba et al. 2023) suggests the use of a pet robot with a glove, a dumbbell, and a gamebox. Physical activity is mainly targeted but the cognitive functions are also addressed by engaging interactions with the pet robot. A further paper (Mirkovic and Wolff 2024) suggested a robot with multimodal interaction. The robot can namely interact with the dementia patient with multiple physical exercises: ball throwing, high-five, and strength exercise. Only one paper (Maroto-Gómez et al. 2022) proposed entertainment activities via a social robot. The idea is to promote longer-lasting interactions with patients.

4.4 Architecture questions

Figure 6 shows the distribution of the used machine learning techniques (Arch_RQ1). Deep learning was the most frequent machine learning technique. The papers that have used such an approach are mainly those that have suggested chatbots. Over the last few years, chatbots have received a lot of attention, and more and more are using deep learning. The use of large language models for chatbots has many advantages, such as human-like interaction, the ability to maintain the context of the conversation, the possibility of using pre-trained large language models, and the integration of human feedback for continuous learning. Apart from chatbots, other papers have also used convolutional neural networks for image processing, or deep learning services which offer great performance compared to classical machine learning. More specifically, the following deep learning techniques were used:

- Convolutional Neural Network (CNN): Carós et al. 2020; Abirami et al. 2024; Sharma et al. 2024
- Long Short-Term Memory (LSTM): Carós et al. 2020
- Artificial Neural Network (ANN): Upadhyay 2023
- Transformer: Konapur et al. 2021
- Encoder and Decoder: Jiang et al. 2023

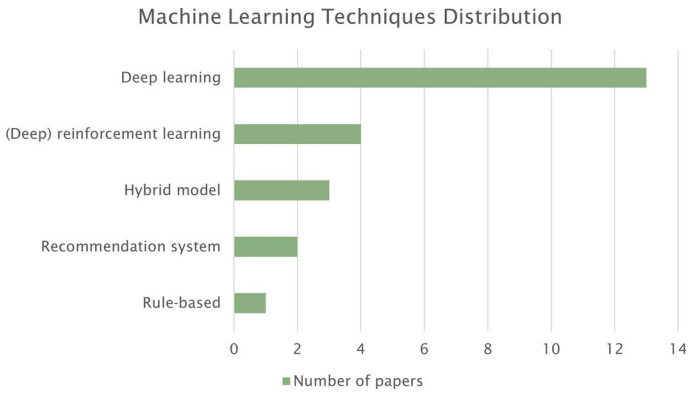

Fig. 6 Machine learning techniques distribution

Among deep learning techniques, seven papers also mentioned the use of machine learning services. Four papers (Ronquillo et al. 2020; Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020, 2020) reported on the utilization of IBM Watson (IBM n.d.). More specifically, the Speech-to-text, Language Translator, and Tone Analyzer services were mentioned. Another paper (Hruška et al. 2020) used the Microsoft's Face API (Microsoft n.d.) to detect the emotions of patients. One paper (Sheba et al. 2023) used the BlazePose body tracking model by Google (Bazarevsky et al. 2020) and two papers (Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020) used the SpeechtoText1 service also offered by Google (Google n.d.). A further paper (Wang and Zhang 2024) used ChatGPT (OpenAI n.d.) to create prompts based on the input of the patient and then sent them to DreamStudio (Stability AI n.d.) to generate an image of the patient's memory.

All the papers that mentioned the use of reinforcement learning proposed serious games. Indeed, the virtual assistant was taught the game through reinforcement learning. The following (deep) reinforcement learning techniques were used:

- Deep Q-Network (DQN): Joypriyanka et al. 2023c, a
- Asynchronous Advantage Actor Critic (A3C): Joypriyanka et al. 2023d
- Soft Actor-Critic (SAC): Joypriyanka et al. 2023bA hybrid model was mentioned in three papers. One paper (Rathnayaka et al. 2021) that suggested a serious game used Q-Learning for next-level difficulty prediction and a Hidden Markow Model (HMM) for speech-to-text communication. Another paper (Maroto-Gómez et al. 2022) described the combination of preference learning to predict the user's favorite entertainment activities and reinforcement learning to adapt the prediction while the entertainment session occurs. Another paper (Mirkovic and Wolff 2024) combined rule-based systems and evolutionary algorithms. It uses a fuzzy logic to classify the degree of dementia and then adapts the exercises in a rule-based manner based on knowledge from expert caregivers. A further paper (Kariyawasam et al. 2023) suggested a recommendation system based on content, collaborative filtering, and K-Nearest Neighbor (KNN). Another paper (Llorente et al. 2024) also suggested a recommendation system which analyzes data from games to evaluate the cognitive status of patients. Based on this evaluation, it then provides personalized notifications to patients to promote engagement and improve the user experience. A single paper (Eun et al. 2023) proposed a rule-based learning system to adjust the difficulty of games.

Figure 7 shows whether the therapies proposed in the papers also provided dementia tracking (Arch_RQ2). In fact, it would be interesting to know whether the dementia state changes as the patient completes the therapy. Dementia tracking was provided in only six of the twenty-three analyzed papers. In one paper (Upadhyay 2023), a new cognition profile is generated after each virtual reality therapy session. These cognition profiles can then be visualized by care providers to analyze the trends in a dashboard. Another paper (Kariyawasam et al. 2023) also suggested a dashboard for caregivers, which offers a view of the patient's physical therapy progress, including monthly scores. A further paper (Rathnayaka et al. 2021), which proposed a mobile phone serious game, also offers functionality to send patient's progress including game scoring as a report via email. Then, the care providers can analyze these email reports. In the paper that suggests a pet robot (Sheba et al. 2023),

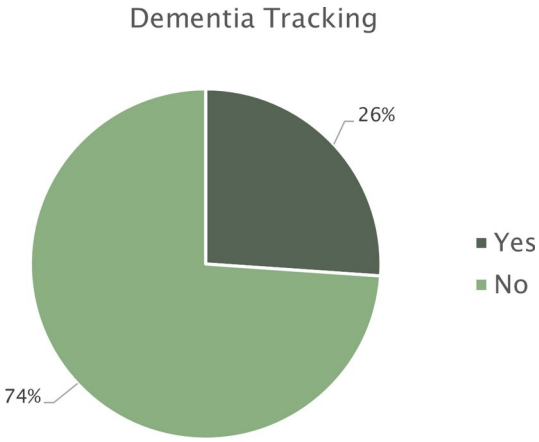

Fig. 7 Dementia tracking

the interactions and activities are saved in the cloud and can be further analyzed to monitor patient's progress. In another paper suggesting serious games (Llorente et al. 2024), cognitive characteristics are collected during games to evaluate the cognitive status and follow evolution. Each week, patients then receive notifications depending on their metrics ans scores. The cognitive status metrics can also be accessed by clinical experts to follow the evolution of patients. In a further paper proposing a robot with physical games (Mirkovic and Wolff 2024), inputs like speech, facial expressions, gestures, and biosignals are used to track the progress of the patient. This collected data then allows to classify the degree of dementia and thus follow the evolution over time.

4.5 Performance evaluation questions

The papers are grouped into categories according to their respective machine learning techniques, to facilitate the comparison of their performance (Perf_Eval_RQ3). Table 4 shows the different machine learning techniques with their corresponding papers and metric scores. As it can be observed, it was difficult to find scores to compare the different papers. Either the used metrics are not the same, or sometimes no metric is mentioned. However, the best accuracy scores were obtained using deep learning methods (Upadhyay 2023; Sheba et al. 2023; Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020; Abirami et al. 2024; Sharma et al. 2024). Among the papers using deep learning, two papers (Konapur et al. 2021; Jiang et al. 2023) used BLEU scores which were high, indicating that the generated text is of good quality. The therapies using (deep) reinforcement learning all have accuracy metrics, which enables ranking two papers (Joypriyanka and Surendran 2023a, b) as the best performers, with an accuracy of 85.2%. Only one recommendation model had an accuracy metric, which reached 80%. No machine learning metric was indicated in papers with hybrid and rule-based models.

It would be interesting to know whether the suggested therapies can really slow down the progression of dementia, or even reverse it (Perf_Eval_RQ2). In Table 4, such metrics are referred to as "dementia metric" and are provided by six papers (Upadhyay 2023; Kariyawasam et al. 2023; Eun et al. 2023; Rathnayaka et al. 2021; Llorente et al. 2024; Abirami et al. 2024). One paper (Upadhyay 2023) conducted a study during six months with a weekly virtual reality therapy. It included 14 dementia patients split into two groups: a control group

Table 4 Performance evaluation using metrics

Machine Learning Technique	Paper	More Precise Technique	Metric Scores
Deep learning	Carós et al. (2020)	Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM)	–
	Upadhyay (2023)	Artificial Neural Network (ANN)	Accuracy of 96% and dementia metric
	Konapur et al. (2021)	Transformer	BLEU score of 33.5
	Jiang et al. (2023)	Encoder and Decoder	BLEU score of 30.90
	Ronquillo et al. (2020)	IBM Watson (IBM n.d.) (Speech-to-text, Language Translator and Tone Analyzer)	–
	Hruška et al. (2020)	Microsoft's Face API (Microsoft n.d.)	–
	Sheba et al. (2023)	Face recognition	Accuracy of 99.38%
		Gesture recognition	Accuracy of 99.7%
	Somodevilla and Morales-de Jesús (2019) and Morales de Jesús and Somodevilla García (2020)	Google Cloud Speech-to-Text API2 (Google n.d.) and IBM Watson Text-to-Speech API3 (IBM n.d.)	–
		Speech acts classification (deep neural network)	Accuracy of 89%
	Leo et al. (2019)	IBM Cloud cognitive platform (IBM n.d.)	–
	Wang and Zhang (2024)	ChatGPT (OpenAI n.d.) and DreamStudio (Stability AI n.d.)	–
	Abirami et al. (2024)	Convolutional Neural Network (CNN)	Accuracy over 85% and dementia metric
	Sharma et al. (2024)	Convolutional Neural Network (CNN) for the emotional model	Accuracy of 65%
		Unspecified for the sentimental model	Accuracy of 89%
(Deep) reinforcement learning	Joypriyanka and Surendran (2023a)	Deep Q-Network (DQN)	Accuracy of 85.2%
	Joypriyanka and Surendran (2023b)	Soft Actor-Critic (SAC)	Accuracy of 85.2%
	Joypriyanka and Surendran (2023c)	Deep Q-Network (DQN)	Accuracy of 76%
	Joypriyanka and Surendran (2023d)	Asynchronous Advantage Actor Critic (A3C)	Accuracy of 78%
Hybrid model	Rathnayaka et al. (2021)	Q-Learning and Hidden Markow Model (HMM)	Dementia metric
	Maroto-Gómez et al. (2022)	Preference learning and reinforcement learning	–
	Mirkovic and Wolff (2024)	Rule-based systems and evolutionary algorithms	–
Recommendation system	Kariyawasam et al. (2023)	Based on content, collaborative filtering and K-Nearest Neighbor (KNN)	Accuracy of 80% and dementia metric

Table 4 (continued)

Machine Learning Technique	Paper	More Precise Technique	Metric Scores
	Llorente et al. (2024)	Multimoda data-driven recommender system	Dementia metric
Rule-based	Eun et al. (2023)	Rule-based difficult adjustment	Dementia metric

of 4 patients and an experimental group of 10 patients. The results were very positive: the dementia patients in the experimental group then had a 65% slower rate of cognition degeneration, 59% better quality of life, and 60% better working memory. These are promising results, although the patient groups were relatively small. Another paper (Kariyawasam et al. 2023) provided a metric based on activity engagement, which was calculated with the aerobic, anerobic, and balance scores of patients. Four dementia patients used the proposed therapy for one month, which resulted in 12% gain in activity engagement. In another paper (Eun et al. 2023), the initial game scores, after one month, and after three months of therapy were compared. It was shown that there was a big increase in the scores after one month and after three months. The authors of the paper considered this increase to be valid evidence that the physical and cognitive abilities of the patients have improved, as the exercises of the games are closely related to both abilities. A further paper (Rathnayaka et al. 2021) showed that after a month of therapy with dementia patients, their attention and concentration, executive functions, language, and memory improved positively. In a paper that suggests serious games (Llorente et al. 2024), two metrics were defined, namely the cognitive state score, which is derived from game performance, and the deviation in cognitive abilities from the patient's baseline. A 3-month study involving 93 patients (comprising Alzheimer's and Parkinson's disease patients) showed a slight improvement in cognitive state scores in dementia patients. In a further paper also suggesting serious games (Abirami et al. 2024), user testing showed a significant improvement in engagement and skill scores over time.

Ideas for further improvement are discussed (Perf_Eval_RQ3) hereafter. Only ideas for future research and improvements in the field are considered. Improvement ideas for specific solutions such as model parameters are not addressed further.

A paper (Joypriyanka and Surendran 2023a) suggested the use of standardized cognitive tests to measure memory abilities before and after therapy. In fact, the use of standardized tests could help to better assess performance and compare therapies. The same paper also highlights the potential of the DQN algorithm for application in the context of serious games.

The authors of another paper (Jiang et al. 2023) plan to build larger datasets of Mandarin and Cantonese conversations to train models. As already mentioned in Subsect. 4.2, very few, if any, specific datasets exist. It is therefore important that datasets are created in the future specifically for dementia research. The authors of another paper (Eun et al. 2023) also outlined their future plans to increase the size of their dataset.

The authors of four papers mentioned that they plan to carry out experimentations with patients. In one paper (Morales de Jesús and Somodevilla García 2020), it is planned as future work to test the conversational system with patients with an early stage of Alzheimer's disease. In another paper (Leo et al. 2019), a test with patients with early dementia is already scheduled. The authors of further paper (Wang and Zhang 2024) plan to include volunteers with memory challenges to evaluate how the suggested therapy affects memory and

how the user experience is perceived. In the paper suggesting a robot for physical therapy (Mirkovic and Wolff 2024), the next step is to certify the safety of the robot. Afterwards, it is planed to evaluate the robot in a nursing home with real dementia patients.

A further paper which suggests a serious game (Eun et al. 2023) planed as future work to grow the number of patients involved in the testing. This would increase the reliability of the results. However, it is difficult to find volunteer patients, as mentioned in another paper (Carós et al. 2020).

4.6 Usability questions

First, the language in which therapies are available is analyzed (Usability_RQ1). This aspect is relevant to discovering for which audiences the therapies have been developed. Indeed, the language distribution provides a better picture in terms of inclusivity and accessibility for patients. Table 5 shows the language availability distribution of the proposed therapies. A therapy can be available in several languages.

For most papers (Carós et al. 2020; Joypriyanka and Surendran 2023a, b, c, d; Upadhyay 2023; Ronquillo et al. 2020; Konapur et al. 2021; Eun et al. 2023; Wang and Zhang 2024; Llorente et al. 2024), the available therapy languages were not explicitly specified. The screenshots or pictures of the suggested therapy and the populations tested (where applicable) were therefore analyzed to deduce the languages available. For four papers (Maroto-Gómez et al. 2022; Sheba et al. 2023; Abirami et al. 2024; Mirkovic and Wolff 2024), no information could be deduced and therefore appear as unspecified in the bar chart. Most of the proposed therapies were available in English. Three were available in Spanish. Other languages appeared only once. One paper (Kariyawasam et al. 2023) stated that the patients who tested the therapy appreciated that it was available in Sinhala. This shows that availability in the local language is important for populations with little or no knowledge of English.

Apart from the language of the suggested therapy, how the patient can benefit from it is also relevant. Table 6 shows the distribution of how patients can complete the therapy

Table 5 Language availability

Language	Number of Papers	Papers
English	12	Carós et al. 2020; Joypriyanka et al. 2023a, b, c, d; Upadhyay et al. 2023; Rathnayaka et al. 2021; Kariyawasam et al. 2023; Konapur et al. 2021; Wang et al. 2024; Llorente et al. 2024; Sharma et al. 2024
Spanish	3	Somodevilla et al. 2019; Morales de Jesús et al. 2020; Ronquillo et al. 2020
Sinhala	1	Rathnayaka et al. 2021
Chinese	1	Jiang et al. 2023
Czech	1	Hruška et al. 2020
Italian	1	Leo et al. 2019
Korean	1	Eun et al. 2023
Unspecified	4	Maroto-Gómez et al. 2022; Sheba et al. 2023; Abirami et al. 2024; Mirkovic et al. 2024

(Usability_RQ2). Note that one therapy can be offered in several mediums. Some papers (Joypriyanka and Surendran 2023a, b, c, d; Jiang et al. 2023; Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020; Sharma et al. 2024) did not specify the medium through which therapy would be offered to dementia patients. In these cases, the medium was deduced from the screenshots and the information available in the paper. It turned out that the smartphone/tablet and laptop mediums were assigned to all of these papers.

Most of the suggested therapies would be accessible to patients via smartphone/tablet. According to a 2021 study, 61% of American adults over 65 own a smartphone (Pew Research Center 2022). This would exclude a significant proportion of the elderly, unless smartphones are provided for therapy. A little bit less than half of all therapies would also be available on a laptop. Some other papers proposed the therapy via a robot (Hruška et al. 2020; Maroto-Gómez et al. 2022; Sheba et al. 2023; Mirkovic and Wolff 2024) or via virtual reality (Upadhyay 2023; Ronquillo et al. 2020; Wang and Zhang 2024). One paper (Eun et al. 2023) suggested a combination of a personal computer and a Kinect camera. Robots, virtual reality, and Kinect cameras are not mediums that everyone has at home. In such cases, the patient would either have to go elsewhere to benefit from the therapy or rent/purchase the missing equipment. In another paper (Abirami et al. 2024), a Raspberry Pi was used to showcase the affordability and accessibility of the suggested therapy. It is however not clear on which device the therapy would be offered and thus appears as unknown in the table.

At this point, it would be interesting to know what dementia patients thought about the therapies. Only seven papers (Carós et al. 2020; Upadhyay 2023; Kariyawasam et al. 2023; Ronquillo et al. 2020; Hruška et al. 2020; Eun et al. 2023; Llorente et al. 2024) provided a patient review of the proposed therapy. Two further papers (Rathnayaka et al. 2021; Abirami et al. 2024) also had patients test the therapy, but the results were not detailed enough to

Table 6 Therapy Medium

Medium	Number of Papers	Papers
Smartphone/Tablet	14	Carós et al. 2020; Joypriyanka et al. 2023a, b, c, d; Rathnayaka et al. 2021; Kariyawasam et al. 2023; Konapur et al. 2021; Jiang et al. 2023; Somodevilla et al. 2019; Morales de Jesús et al. 2020; Leo et al. 2019; Llorente et al. 2024; Sharma et al. 2024
Laptop	9	Joypriyanka et al. 2023a, b, c, d; Konapur et al. 2021; Jiang et al. 2023; Somodevilla et al. 2019; Morales de Jesús et al. 2020; Sharma et al. 2024
Robot	4	Sheba et al. 2023; Hruška et al. 2020; Maroto-Gómez et al. 2022; Mirkovic et al. 2024
VR	3	Upadhyay et al. 2023; Ronquillo et al. 2020; Wang et al. 2024
PC and Kinect camera	1	Eun et al. 2023
Unknown	1	Abirami et al. 2024

Table 7 Patient testing

Paper	Number of patients	Cognitive state of patients	Duration	Patient's feedback	Needed help during therapy?
Carós et al. (2020)	4	2 with mild cognitive impairment, 2 healthy adults over 60	One single 30-minute session	Amusing: 4.6/5, Engaging: 4.6/5, Difficulty: 2.6/5, all users reported to enjoy the therapy	It is essential to have a person to support the users to help them remember the asked questions
Upadhyay (2023)	14	Patients with varying stages of dementia (4 in the control group and 10 in the experimental group)	Weekly during 6 months for the experimental group and monthly for the control group	The patients found the therapy very enjoyable	There is no need for expert supervision. However, patients need a virtual reality device and an internet connection
Kariyawasam et al. (2023)	2	Patients with early-stage Alzheimer's disease	One month	The patients were happy to use smartphones, appreciated the application's language (Sinhala) and program's flow	Patients need follow-up instructions
Ronquillo et al. (2020)	4	Adults with no cognitive impairment diagnostic from 67 to 77 years old	One session	Good acceptance by patients, who reported that the application was in general easy to use. Tested patients would like to use the application with some frequency	Patients think that the assistance of a facilitator during the session is important
Hruška et al. (2020)	10	Adults from a pensioner care center	Two sessions	The majority of patients enjoyed the sessions	An assistant sometimes had to repeat questions for hearing-impaired patients
Eun et al. (2023)	25	Elders from 60 to 80 years old	Three months	The therapy is not too difficult for patients to follow. High acceptability was observed	This question was not addressed in the paper, but since a PC and a Kinect camera are used, it is assumed that patients need some form of assistance
Llorente et al. (2024)	93	Patients with Alzheimer's or Parkinson's disease over 65 years old	Three months	Patients found the therapy engaging and user-friendly	The presence of a caregiver was crucial to ensure patient engagement

be included here. Table 7 shows the details of the testing by patients (Usability_RQ3) and whether patients needed help to perform the therapy (Usability_RQ4).

In most papers, the number of patients is quite low. As stated in one paper (Carós et al. 2020), the experiment could not be carried out with more patients, as no more volunteered to take part. Another paper (Eun et al. 2023) also pointed out that the number of participants needs to be increased to strengthen the statistical result. Regarding the cognitive status of patients, only a few diagnosed with dementia participated, and even less with advanced Alzheimer's disease. This is probably due to the difficulty of finding patient volunteers,

as already mentioned. Most tests were carried out over a short period of time. Among the longest test durations, three studies were conducted over periods of three (Eun et al. 2023; Llorente et al. 2024) and six months (Upadhyay 2023). Regarding patient feedback, it was very positive in all usability tests, indicating high acceptability. Another important aspect is whether the patient can complete the therapy independently. For all the suggested therapies, it turned out that the presence of an assistant would be preferred. Indeed, people with dementia sometimes need questions to be repeated, require assistance to stay motivated, or have hearing problems that complicate communication. Patients also thought that the presence of an assistant during therapy sessions is important (Ronquillo et al. 2020).

4.7 Ethical questions

As the studied papers deal with the medical field, and some have collected patient data and carried out acceptance tests with patients, ethical questions arise (Ethics_RQ1). All the databases from which papers were retrieved, apart from Google Scholar, adhere to ethical guidelines. ACM Digital Library (ACM Digital Library n.d.) and ACL Anthology (ACL Anthology n.d.-a) publications must comply with the ACM Code of Ethics and Professional Conduct (Association for Computing Machinery n.d.). Regarding IEEE Xplore (IEEE n.d.-b) papers, they must adhere to the IEEE Code of Ethics (IEEE n.d.-a). ScienceDirect (Elsevier n.d.-b) publications must comply with Elsevier Publishing ethics (Elservier n.d.-a). Springer (Springer Link n.d.) adheres to the Committee on Publication Ethics (COPE) which goal is to promote integrity in research (COPE n.d.). These guidelines contain general ethical rules and must be checked when papers are submitted.

Only three papers contained some additional ethical considerations. One paper (Joypriyanka and Surendran 2023d) briefly mentioned some of the ethical concerns associated with artificial intelligence. It underlined the issues of responsibility, accountability, and system reliability. The challenge posed by the potential use of fake data was also shortly mentioned. Before the test session described in a further paper (Ronquillo et al. 2020), patients were provided with an informed consent document and an informative flyer. Both documents were ethically approved by the Alzheimer's Foundation Memory Institute (AFMI). In another paper (Jiang et al. 2023), the authors specified that they sought to ethically conduct the study. To this end, they communicated transparently with the data annotators about the use of the data and the purpose of the study. They also tried to find suitable seniors and to remunerate them at a reasonable hourly wage. In addition, an ethics review board approved the study. The ACL 2023 Responsible NLP Checklist (ACL Anthology n.d.-b) was also utilized to ensure responsible research.

5 Discussion

In this paper, a systematic literature review following the PRISMA guidelines (PRISMA 2020) was performed. The aim was to discover the current state of research into dementia therapies based on machine learning. Twenty-three papers were selected and analyzed according to the research questions defined in Subsect. 3.2. First, the leading countries in terms of publication of papers are discussed in Subsect. 5.1. Then, the lack of available datasets is addressed in Subsect. 5.2, followed by a discussion about the therapy types in Sub-

sect. 5.3. The need for a standardized metric and for more volunteer patients are discussed in Subsect. 5.4, respectively in Subsect. 5.5. Then, the autonomy of patients in performing the therapy is addressed in Subsect. 5.6. The available devices and languages of the various therapies are discussed in Subsect. 5.7. Finally, the need for more ethical considerations is described in Subsect. 5.8.

5.1 Growing interest led by Asian countries

There has been an increasing number of papers in the field over recent years, indicating a probable growing interest in the subject. Most of the papers were written by authors from Asian universities, while very little research was carried out in Europe and in the US. This growing interest in Asian countries and especially in India is probably also influenced by national strategies as described in Subsect. 4.1. However, Southern Europe is currently the oldest region in the world, with 21% of the population aged 65 and older (Population Reference Bureau 2020). According to the World Health Organization, there is a lack of awareness and knowledge about dementia in Europe, resulting in stigmatization and discrimination that hinders the development of diagnosis and therapies (World Health Organization 2024). It is therefore important that future research is carried out not only in Asia, but also in Europe and other parts of the world to find effective and accessible ways of combating dementia disorders.

5.2 Lack of suitable datasets

Open-source datasets specific to the dementia field are lacking and are slowing down research. Moreover, finding datasets in languages other than English makes the task even more challenging. As a result, the authors of some of the studied papers (Maroto-Gómez et al. 2022; Jiang et al. 2023) created their own datasets to meet their needs. In the future, creating datasets in different languages would be very beneficial for research in this field.

5.3 Room for new types of therapy

Most of the analyzed papers proposed therapy with serious games (Joypriyanka and Surendran 2023c, d, a, b; Eun et al. 2023; Upadhyay 2023; Rathnayaka et al. 2021; Llorente et al. 2024; Abirami et al. 2024), dialog systems (Jiang et al. 2023; Carós et al. 2020; Konapur et al. 2021; Somodevilla and Morales-de Jesús 2019; Morales de Jesús and Somodevilla García 2020), virtual reality (Ronquillo et al. 2020; Upadhyay 2023; Wang and Zhang 2024), and robots (Hruška et al. 2020; Maroto-Gómez et al. 2022; Sheba et al. 2023; Mirkovic and Wolff 2024). It is also likely that other therapies are possible. Closer collaboration with physicians and dementia specialists would help identify further ideas. In fact, they are the ones who know most about dementia and how patients would react to potential therapies.

5.4 Need for a standardized metric

The usual metrics such as accuracy, recall, and F1 are not the most useful when it comes to demonstrating the effectiveness of therapy. Indeed, there is a need for a standardized metric to assess the effectiveness of therapy on dementia. Some papers (Upadhyay 2023; Kariya-

wasam et al. 2023; Eun et al. 2023; Rathnayaka et al. 2021) have used their own metrics, but it is then difficult to compare them. Being able to track progress is important and could also keep patients motivated to continue therapy.

5.5 Need for more volunteer patients

Less than half of the papers conducted a usability test with patients. Even though the feedback was very positive, the number of patients was low. This is due to the difficulty of finding patient volunteers as mentioned in one paper (Carós et al. 2020). Only few of the patients taking part in the usability tests were diagnosed with more advanced dementia stages such as Alzheimer's disease. There is therefore a need to expand the patient sample to obtain more robust results, as mentioned in another paper (Eun et al. 2023). In addition, the patients should be selected according to the targeted dementia degree (mild cognitive impairment, Alzheimer's disease, etc.). This would allow to measure results and perform meaningful comparisons among patients with the same state of dementia.

5.6 Patients need assistance

Real-life usability tests with patients have also shown that some of them needed assistance to complete the therapy. Indeed, patients sometimes required an assistant to remind them of the question asked by the robot (Carós et al. 2020). For therapies with virtual reality or Kinect cameras, it is also unlikely that patients will be able to use the system all by themselves. Moreover, patients reported that they find the presence of an assistant important (Ronquillo et al. 2020). In another paper (Llorente et al. 2024), it was outlined that the presence of a caregiver was essential to ensure patient engagement. For most therapies, the assistant could be an ordinary person, such as a family member or a friend. Indeed, most therapies are easy for a cognitively healthy person to complete. It would also be conceivable for several people to undergo therapy in a single location, with the presence of an assistant who can help them with any problems. This would allow to reduce medical staff costs.

5.7 Device and language availability

Although almost all therapies are available on smartphones, not all elderly own such a device (Pew Research Center 2022). These should then be made available to patients for therapy. The language in which the therapy is available is also important. It is essential to be able to offer therapy in local languages, as stated in one paper (Rathnayaka et al. 2021).

5.8 More ethical considerations

Ethical issues were not given much consideration in the various papers. Many of the papers, however, used patient data and conducted usability tests under real-life conditions. In the future, more importance should be given to ethical considerations, for example by including an ethics committee as in described in one paper (Jiang et al. 2023).

6 Conclusion

6.1 Key findings

This systematic literature review identified several key findings on machine learning-based therapies for dementia. First, the number of papers published has been growing in recent years, especially in Asian countries. Due to the difficulty of finding suitable data, most papers suggested machine learning techniques without the need for databases. Regarding the types of therapies used, they varied considerably, as did the machine learning techniques employed. Because of these different techniques, the machine learning metrics used were difficult to compare. Nevertheless, the results obtained were very positive. Some papers also conducted real-life tests with patients, with very encouraging results both in terms of usability and impact on dementia progression. Regarding ethical considerations, they did not receive much attention.

6.2 Limitations of the review process

The present systematic literature review faces certain limitations. Firstly, it is possible that some papers have not been taken into consideration, as they may be available in databases other than those analyzed. Despite intensive research and careful wording of the search query, it remains possible that some papers may have been inadvertently omitted. Only twenty-three papers were included in this systematic literature review, and results should be interpreted accordingly. In fact, research questions were mainly discussed qualitatively, with the aim of explaining the results and discovering areas for future improvement. Initially, it was also planned to compare the results of the selected papers in more detail, in particular by using statistical methods. However, the selected papers turned out to be very heterogeneous in terms of data and methods. Moreover, only nine of the twenty-three papers conducted trials with patients. Of these nine papers, only two reported having set up test and control groups. Given the heterogeneity of the therapies and the lack of comparable result data, it was not possible to analyze the results in greater detail.

6.3 Future directions

Despite the growing attention for machine learning-based therapies for dementia, several points deserve further attention in future research. Firstly, datasets need to be created to facilitate research and enable data-driven machine learning approaches. In order to find new types of therapy, closer collaboration with physicians might also be beneficial. With regard to the evaluation of therapies, the creation of a standardized metric would be very valuable in guiding future research. Concerning studies with patients, it is vital to be able to include more voluntary patients, especially those with advanced dementia such as Alzheimer's disease. It is equally important that therapies are made available in the widest range of languages, so that the greatest number of patients can benefit from them. Finally, greater attention should be paid to ethical considerations, especially when patients with advanced stages of the disease are involved, which could present issues of consent. In conclusion, based on this systematic literature review, there is undoubtedly a potential for using machine learning-based therapies to treat dementia.

7 Glossary

Reinforcement learning (RL): Reinforcement learning is one of the three machine learning paradigms, together with supervised and unsupervised learning. Reinforcement learning consists in learning behaviors adapted to a particular situation in order to maximize reward. It is self-teaching, learning by trial and error.

Deep learning (DL): Deep learning is a field of machine learning that uses neural networks. These attempt to imitate the human brain and consist of three or more layers. Typically, large amounts of data are required for training.

Deep reinforcement learning: Deep reinforcement learning is a type of machine learning that combines reinforcement learning and deep learning.

Convolutional Neural Network (CNN): A Convolutional Neural Network is a type of neural network which is often used for computer vision tasks such as image classification, detection and segmentation. The more layers there are in the Convolutional Neural Network, the larger portions of the image are identified.

Long Short-Term Memory (LSTM) (Hochreiter and Schmidhuber 1997): Long Short-Term Memory is a type of enhanced recurrent neural network (RNN). It solves the vanishing gradient problem and provides feedback connections for learning dependencies in sequential data. Long Short-Term Memory is therefore well suited to tasks involving time series and sequences, such as machine translation and speech recognition.

Artificial Neural Network (ANN): An Artificial Neural Network is a machine learning model inspired by the human brain. It consists of nodes which are called artificial neurons, which model the neurons of the brain. Artificial neurons are arranged in layers. Usually, Artificial Neural Networks consist of an input layer, hidden layers that perform data transformations, and an output layer.

Transformer (Vaswani et al. 2017): The transformer is a type of neural network designed for sequence-to-sequence tasks. The self-attention mechanism of the transformer architecture enables the model to weigh the importance of the different words in a sentence. It is therefore particularly effective for tasks such as language translation and text summarization.

Encoder: In the encoder-decoder architecture, the encoder is the first part which receives an input and has to understand and extract the relevant information from it. The encoder then generates an embedding of the input, which is subsequently processed by the decoder.

Decoder: The decoder is the second part of the encoder-decoder architecture. The decoder receives the embedding of the encoder, and decodes it to produce the desired output.

Deep Q-Network (DQN): Deep Q-Network is a reinforcement learning algorithm that uses a deep neural network. The goal is to approximate the Q-function that estimates the expected reward for a given action in a given state. There are various applications for deep Q-Network, such as games and autonomous vehicles.

Asynchronous Advantage Actor Critic (A3C): Asynchronous Advantage Actor Critic is a reinforcement learning algorithm that uses deep learning. Multiple agents interact with their own environment asynchronously. This allows multiple paths to be explored, leading to improved performance.

Soft Actor-Critic (SAC) (Haarnoja et al. 2018): Soft Actor-Critic is a deep reinforcement learning algorithm based on entropy maximization. The goal is to maximize the expected reward and the entropy of the policy.

Q-learning: Q-learning is a reinforcement learning algorithm which goal is to find the best series of actions based on the current state of the agent.

Hidden Markow Model (HMM): A Hidden Markow Model is a statistical model in which the system being modeled is assumed to be a Markov process. The system states themselves (hidden) cannot be observed, only the outputs. The aim is to use probabilities to describe the transitions between the hidden states and the observed outputs.

Preference learning: Preference learning is a subfield of machine learning whose goal is to learn and predict user preferences. Several techniques can be used, such as content filtering and collaborative filtering.

Content filtering: Content-based filtering is a preference learning technique in which recommendations are formulated based on the characteristics of the items and those of the user.

Collaborative filtering: Collaborative filtering is a preference learning technique. There are two common types of collaborative filtering: user-based and item-based. User-based collaborative filtering makes recommendations based on the preferences of similar users, while item-based collaborative filtering makes recommendations based on the similarity of items.

K-Nearest-Neighbor (KNN): K-Nearest-Neighbor is a supervised learning algorithm that finds the K nearest neighbors to a given data point. It then lets a majority vote or average of the K neighbors determine the class or value of the data point.

Rule-based learning: Rule-based learning is a machine learning technique in which the model generates rules from the data. These rules are then used to make predictions. An example of rule-based learning is decision trees.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10462-024-11084-8.

Declarations

Conflict of interest We declare that the authors have no Conflict of interest as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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