Exploring Intervention Techniques for Alzheimer's Disease: Conventional Methods and the Role of AI in Advancing Care

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Abstract: Alzheimer's disease (AD) is a neurodegenerative condition characterized by cognitive decline and functional impairment. This study compares conventional intervention techniques with emerging artificial intelligence (AI) approaches to AD. Intervention technique refers to a specific method or approach employed to bring about positive change in a particular situation. In the context of AD, such techniques are crucial as they aim to slow down the progression of symptoms, alleviate behavioral challenges, and support patients and their caretakers in managing the complexities of the condition. Conventional intervention techniques, such as cognitive stimulation and reality orientation, have demonstrated benefits in improving cognitive function and emotional well-being. Conventional intervention approaches are widely preferred as they have a proven track record of effectiveness, personalized response, cost-effectiveness, and patient-centered care. Despite these benefits, they are limited by individual variability in response and long-term effectiveness. On the other hand, AI-based approaches such as Computer Vision and Deep Learning (DL) offer early detection, tailored interventions, assist decision-making, and enhance caregiver support. Although AI-based interventions face challenges such as data privacy and implementation complexity, their potential to revolutionize Alzheimer's interventions is significant. This research paper compares conventional and AI-based approaches. It reveals that while traditional techniques are well-established and have proven benefits, AI-based interventions offer novel opportunities for personalized and advanced care. Combining the strengths of both approaches may lead to more comprehensive and effective interventions for individuals with AD. Continued research and collaboration are crucial to harness the full potential of AI in improving Alzheimer's care and enhancing the quality of life for affected individuals and their caregivers.

Keywords: Alzheimer's Disease, intervention techniques, conventional methods, artificial intelligence, cognitive stimulation, reality orientation, reminiscence therapy

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Natural Language Processing (NLP), and Machine Learning (ML) techniques, has shown promising potential for enhancing Alzheimer's interventions. This introduction will provide an overview of these approaches and their application in the context of AD, highlighting the benefits and challenges associated with their integration.

Conventional interventions for AD have long been employed to address cognitive decline, maximize functional independence, enhance quality of life for individuals with the condition. Cognitive stimulation therapy, for instance, engages individuals in various cognitive exercises and activities to maintain cognitive abilities and foster social interaction (Spector et al., 2011). Reminiscence therapy focuses on stimulating memories and promoting a sense of identity through photographs, music, and storytelling (Woods et al., 2018). These interventions have demonstrated positive effects on cognition, mood, and overall well-being in individuals with AD.

Deep Learning, a subset of ML, has gained significant attention in recent years due to its ability to analyze complex patterns and learn from large datasets. DL techniques have been employed in various domains, including medical imaging, genomics, and clinical records. For instance, DL models trained on neuroimaging data have shown promising results in accurately detecting and predicting AD progression (Cheng et al., 2019). These models can identify subtle changes in brain structures and biomarkers, enabling early diagnosis and intervention.

Vision Transformers, a novel architecture within Computer Vision, has emerged as a powerful tool for analyzing visual data. Unlike traditional Convolutional Neural Networks (CNNs), which operate on fixed-sized grids, ViT employ self-attention mechanisms to capture long-range dependencies within images. This capability makes them well-suited for tasks such as object detection, image segmentation, and classification. ViT for AD can be utilized to analyze medical imaging data, enabling the detection of neurodegenerative changes and abnormalities associated with the disease (Xing et al., 2022). The ViT architecture is assessed for AD detection. The original version of the model was developed for NLP tasks. However, the development of its adaptation to Computer Vision tasks is being implemented at a fast pace. Efficient algorithms for AD diagnosis, and early detection, in particular, are a pivotal area in medical imaging research. The study by (Xing et al. 2022) evaluates the potential of the ViT model for processing multi-modal PET images, such as PET-AV-45 and PET-FDG, for AD classification. It is suggested that the use of the ViT model together with the self-attention mechanism and 3D-to-2D conversion module will enhance both the efficiency and accuracy of AD diagnosis. By leveraging the power of ViT, more accurate and efficient analysis of visual data can be achieved.

Natural Language Processing, another branch of AI, focuses on understanding and generating human language. NLP techniques have been extensively used in various healthcare domains, including AD research. In the context of Alzheimer's interventions, NLP can be employed for tasks such as language modeling, sentiment analysis, and text generation. For instance, NLP models can generate personalized narratives, reminders, and instructions tailored to individuals with Alzheimer's, aiding in memory retention and daily task management. NLP can also facilitate natural language interactions and communication, improving engagement and social interactions for individuals with Alzheimer's.

ML techniques encompass a wide range of algorithms and approaches that enable computers to learn from data and make predictions or decisions. ML techniques for AD detection have been applied to various data sources, including genetic information, clinical records, and behavioral data (Cheng et al., 2015). These techniques can be utilized for tasks such as early detection, predicting disease progression, and personalizing treatment strategies. The articles (Noushath et al., 2024) explores machine learning techniques on the Alzheimer's Disease Neuroimaging Initiative (ADNI) and OASIS datasets to classify AD stages. The results show that a smaller number of diverse machine learning ensemble outperforms the state-of-the-art CNN centric models (Noushath et al., 2022).

The integration of these advanced technologies with conventional interventions holds great promise for enhancing Alzheimer's interventions. By leveraging DL, ViT, NLP, and ML techniques, we can achieve more accurate cognitive assessments, early diagnosis, personalized care, improved communication, and enhanced caregiver support. A simple representation in Figure 1 demonstrates the working of DL, ML and ViT in the prediction of AD. However, the integration of these approaches also presents challenges, including data privacy and ethical considerations, interpretability of AI models, and the need for interdisciplinary collaboration among healthcare professionals, researchers, and technologists.

In this comprehensive review paper, we present a concise yet informative overview of various intervention techniques for AD, encompassing both conventional methods and cutting-edge approaches powered by AI. By synthesizing the latest research findings, our review aims to offer a valuable resource for researchers and clinicians, providing insights into the current state of the art in AD intervention. Tailored to benefit both seasoned professionals and newcomers to this dynamic field, the paper serves as a reference guide, fostering a deeper understanding of the diverse strategies employed in the ongoing quest to address the challenges posed by AD.

The rest of the manuscript is organized as follows: Section 2 discusses the motivation and proposed plan; section 3 presents the survey of conventional intervention techniques. Section 4 presents the survey of intervention techniques based on AI techniques. Important findings of the survey are discussed in Section 5, future works discussed in Section 6 and conclusions are drawn in Section 7.
Figure 1: Demonstrating the working of different AI techniques in predicting AD

2. Motivation and Proposed Plan

The worldwide insurgence of neurodegenerative disorders and the urgent need for efficient diagnostic and intervention strategies are driving exponential growth in the field of AD research. With the significant growth of the aging population, the impact of AD on individuals, families, and healthcare systems becomes increasingly profound. This investigation requires inventive, accurate, and prompt techniques for identifying, forecasting, and intervening in AD in conjunction with the integration of AI methods and the pressing need to tackle the significant global health impact of AD. The rapid progress in Artificial Intelligence (AI) and ML technologies provides unparalleled prospects to transform the conventional diagnostic and intervention approaches for Alzheimer's disease. This investigation requires inventive, accurate, and prompt techniques for identifying, forecasting, and intervening in AD in conjunction with the integration of AI methods and the pressing need to tackle the significant global health impact of AD. The rapid progress in AI and ML technologies provides unparalleled prospects to transform AD's conventional diagnostic and intervention approaches. Additionally, early detection, enabled by AI techniques, is paramount for proactive management, potentially leading to timely therapeutic interventions and lifestyle modifications to curtail the progress of AD.

Motivated by the need to address the challenges of AD, this review explores the landscape of intervention techniques using the latest AI advancements. The proposed plan explores the ethical implications and emphasizes patient and caregiver empowerment. The review also seeks to contribute to the responsible and equitable implementation of AI-driven interventions in the context of AD, ultimately advancing the collective efforts to combat this devastating neurodegenerative disease. In addition to reviewing conventional intervention techniques, we scrutinize both traditional and cutting-edge AI methodologies, providing a comprehensive synthesis of the current state of AI tools and driving the discourse toward innovative solutions that potentially transform the landscape of AD diagnosis and care.
This paper thoroughly examines AD interventions by comparing conventional methods with emerging AI-based approaches. While recognizing the effectiveness of traditional techniques, the article also sheds light on their limitations on individual differences and long-term impact. In contrast, AI technologies like computer vision and DL offer exciting possibilities like remote monitoring, early detection, and personalized care. Despite data privacy challenges and other obstacles, these advancements show great potential for revolutionizing Alzheimer's care.

The article emphasizes the importance of extensive research and collaboration to fully harness the capabilities of AI in transforming Alzheimer's interventions. Integrating traditional and advanced methods is the key to providing comprehensive and effective support, combining the familiarity and cost-effectiveness of conventional techniques with the innovation of AI. By merging these approaches, the article supports improved early detection, personalized care, and overall outcomes for Alzheimer's patients. The scientific community's contribution is critical to the ongoing development of intervention techniques, which is vital in the continued pursuit of enhancing the lives of individuals affected by this devastating disease.

3. Conventional Intervention Techniques

Conventional intervention techniques for AD encompass a multifaceted array of strategies designed to enhance the quality of life and cognitive capabilities of those affected by the condition. Various strategies are categorized to address different aspects of well-being and support. These categories include Cognitive Engagement, Technology Assistance, Therapies, Physical Wellbeing, Mindfulness and Mental Health, Communication Support, Personal Interventions, and Environmental and Caregiver Support (Figure 2). Each category is crucial in providing comprehensive care, contributing to the holistic management of Alzheimer's disease. This section explores the specifics of each intervention category to clarify their distinct contributions and benefits.

Figure 2: Categories of conventional intervention techniques for Alzheimer's disease
3.1. Cognitive Engagement

Cognitive stimulation therapy involves engaging individuals in activities and exercises to improve cognitive functioning, memory, and problem-solving skills (Spector et al., 2010). The article by Lauren et al. (2014) describes the development of individual cognitive stimulation therapy (iCST) for dementia, a home-based intervention delivered by caregivers, based on the Medical Research Council (MRC) framework for complex interventions. The authors reviewed the existing evidence and theory on group and individual cognitive stimulation and consulted with stakeholders and experts. They field-tested the iCST materials with 24 days of people with dementia and their caregivers. The iCST program consists of 75 sessions covering 14 themes and includes a toolkit with a guide for caregivers. The authors report the fundamental changes and feedback from the development process and outline the ongoing evaluation of iCST in a large-scale randomized controlled trial. The systematic review discussed in Wang et al., 2022, narrate cognitive interventions for Alzheimer's disease. Cognitive training positively impacts global cognitive function and short-term depression in the short, medium, and long term, but consistent conclusions for other cognitive outcomes are lacking.

Reality orientation in combination with standard treatment is one of the methods that might be effective in terms of improving cognitive outcome for Alzheimer’s disease patients. In the study (Camargo et al., 2015), patients with AD symptoms who received RO sessions once a week periods over a period of six months along with acetylcholinesterase inhibitors, developed significant cognitive improvements if to compare it to the control group. It seems that RO is a very effective supplementary intervention in the management of dementia among patients with AD.

The authors, Sakina Rao et al. 2022, conducted a systematic review to analyze the efficacy of emotion therapies among individuals with dementia. The review examined 18 studies and focused on various therapies, including simulated presence, reality orientation, validation therapy, animal-assisted therapy, multisensory stimulation, music therapy, and more. The findings indicated positive effects on behavior, assessments, and quality of life in people with dementia. Several studies demonstrated the effectiveness of emotion therapies in reducing problem behaviors, improving cognition, and enhancing mood. Emotion therapies such as music therapy, multisensory stimulation, and mindfulness-based stress reduction were particularly notable for their positive impact on depressive symptoms. Despite positive outcomes, some studies reported limitations and the need for further investigation, especially concerning severe dementia cases. The authors recommended integrating emotion therapies in dementia care to enhance the well-being of individuals with dementia. The review article by Li et al. 2023 analyzes non-drug interventions for AD over the past decade, including cognitive strategies, physical exercise, brain stimulation, and nutritional supplements, to identify effective approaches for symptom improvement.

Sensory stimulation interventions involve using various sensory stimuli, such as touch, smell, and sound, to engage the senses and enhance cognition and well-being in individuals with Alzheimer's. This review (Hayden et al., 2022) explores sensory interventions for older adults with dementia, revealing ten intervention categories and emphasizing their significance in managing dementia-related challenges. In the review article, Yang et al. 2021, explore the benefits of sensory and multisensory stimulation for AD patients. After analyzing literature spanning two decades from 2000 to 2020, the article covers various interventions, including music therapy, aromatherapy, rhythmic stimulation, light therapy, multisensory stimulation, and virtual reality-assisted therapy. The findings suggest that these interventions effectively enhance AD pathology and memory and improve cognition and behavior. Additionally, these interventions induce brain nerve oscillation, boost brain plasticity, and regulate regional cerebral blood flow. The authors highlight the need for further exploration and improvement of the potential mechanisms and stimulation parameters.

3.2 Technology Assistance

Assistive technologies encompass a range of devices and systems that aid individuals with Alzheimer's in daily activities, safety, and communication (Lenca et al. 2017). Expanding on innovative assistive technology, the study by Arthanat et al. 2020, explores a socially assistive robot (SAR) for AD caregivers. The SAR, integrated with IoT sensors, demonstrated the potential of addressing caregiving challenges. Caregivers envisioned SARs as next-gen solutions, emphasizing factors like navigability, engagement, adaptability, humanoid features, and interface design. Acceptance revolved around successful navigation, while barriers included technological complexity and system failures. Caregivers recognized SARs’ role in aging in place but highlighted the importance of timing, commercial viability, funding, and their connection with care recipients. Long-term home-based research is crucial for validating SARs’ impact on the well-being of individuals with AD.

Electronic memory aids include digital calendars, reminders, and voice-activated assistants that help individuals with Alzheimer's manage their daily tasks and appointments (Marziali et al., 2011). In a critical examination of electronic aids for prospective memory in dementia, a study by King et al. (2017), showed a promising outcome. The study also underscores the necessity for further device and software refinement to ensure reliability. Small sample sizes in their studies help generalizability, with a notable gap in research within user’s home environments. The review advocates for future studies with robust devices that explicitly consider the diverse needs of individuals with dementia. Emphasis should extend beyond aid effectiveness, exploring outcomes such as enhanced daily functioning, improved quality of life, and increased social connectedness.

Individuals with Alzheimer's can stay connected using visual aids, symbol-based communication tools, and voice output systems (Ekstorm et al., 2017). The study by Yousaf K. et al. 2020 narrates the realm of mobile health (mHealth) applications catering to dementia, focusing on AD. There are 29 of them curiously selected from 281 articles, unveiling six key mHealth app categories: ADL-based cognitive training, monitoring, dementia screening, reminiscence and socialization, tracking, and caregiver support. Examining 678 commercial apps from the Apple App Store and Google Play Store identified 38 apps that met the inclusion criteria. Despite limited research, the study underscores the promising feasibility and benefits of mHealth apps in enhancing dementia and AD community care.
GPS tracking devices locate individuals with Alzheimer's who may wander and become lost, enhancing their safety and enabling prompt retrieval (Ray et al., 2019). The study by Adardour et al. (2020) presents an innovative IoT prototype, a lightweight dorsal belt equipped with NodeMCU ESP8266, a GPS module, and a WiFi modem/router, enabling real-time location tracking of Alzheimer's patients. Accessible via Android/iOS mobile and web applications, the system utilizes a Kalman Filter to estimate the patient's position, which is crucial for outdoor movements. The research underscores the prototype's efficacy, offering a promising solution to enhance patients' quality of life and support caregivers in their responsibilities.

Ambient assisted living systems use sensors and smart home technologies to support individuals with Alzheimer's in their living environment, ensuring safety and providing reminders (Blackman et al., 2016). The article by Lussier et al. 2020 investigates the concurrent validity of Ambient Assistant Living (AAL) monitoring reports compared to an observation by a caregiver monitoring a 90-year-old Alzheimer's patient, revealing evolving trends in daily activities around 490 days. AAL reports identified significant changes, some unnoticed by the clinical nurse, demonstrating concurrent validity. The study underscores AAL's potential to offer clinically relevant information over time, aiding decision-making in healthcare services and supporting aging in place by addressing the unique challenges of Alzheimer's patients. The author, Herzog (2023), has focused on addressing Mild Cognitive Impairment (MCI), which affects over 15% of people aged 65 and over. He suggests using Ambient Assisted Living (AAL) systems to help manage MCI and assesses their feasibility through an online questionnaire aimed at healthcare professionals. The results indicate strong support for implementing general AAL solutions for MCI patients.

Virtual reality technology creates immersive and interactive environments for individuals with Alzheimer's to enhance cognitive stimulation, reminiscence, and relaxation (Garcia-Betances et al., 2015). In the pilot randomized controlled trial, authors Oliveira et al., 2021, examine the impact of a two-month virtual reality (VR) cognitive stimulation program on individuals experiencing mild-to-moderate dementia due to AD. The study involved 17 participants randomly assigned to experimental and control groups. The VR intervention was designed to replicate daily life activities and comprised ten sessions over two months. Through baseline and follow-up neuropsychological assessments targeting memory, attention, and executive functions, the authors' preliminary findings indicate a significant enhancement in overall cognitive function within the experimental group. The observed large effect size in global cognition suggests the potential effectiveness of VR-based cognitive stimulation for older adults with dementia, emphasizing its role in preserving cognitive function in the context of AD.

3.3. Therapies

Validation therapy focuses on empathetic communication and validating the emotions and experiences of individuals with Alzheimer's, promoting a sense of self-worth and reducing distress (Neal et al. 1996). The review by Goodarzi et al. 2019 addresses AD and the need for effective therapeutic strategies. Focusing on regenerative medicine, the authors emphasize the significance of preclinical stages to validate novel approaches. The review underscores the importance of ethical guidelines in animal studies for understanding biological mechanisms and achieving meaningful outcomes. It provides insights into developing and validating suitable AD animal models, which are crucial for advancing regenerative medicine in the context of this prevalent neurodegenerative disorder. The author Kasula (2023), focuses on a ML approach for AD diagnosis and prognosis, integrating various data sources. The proposed model accurately classifies AD stages and differentiates patients from healthy individuals with high accuracy, sensitivity, and specificity. It also demonstrates promise in predicting disease progression and estimating future outcomes, providing valuable insights for personalized treatment planning.

Reminiscence therapy involves recalling and discussing past experiences to stimulate memories, improve mood, and enhance social interaction (Woods et al. 2018). The study by Cammisuli et al. (2022), explores the efficacy of Reminiscence Therapy (RT) in AD through the analysis of five Randomized Controlled Trials. Administered individually or in groups for 30–35 min/week over 12 weeks, RT significantly improves global cognition, alleviates depression, and enhances Quality of Life. While results highlight RT's potential as a non-pharmacological intervention, the limited number of long-term studies calls for further research. The therapy's cost-effectiveness and positive impact on AD individuals emphasize its role in comprehensive care.

Music therapy involves using music and musical activities to stimulate cognitive function, emotional well-being, and social interaction in individuals with Alzheimer's (McDermott et al., 2013). The article by Matziorinis et al. (2022), provides an extensive review of the potential therapeutic benefits of music therapy (MT) for individuals with AD. Focusing on the unique preservation of musical memory in AD patients, the authors explore how MT can positively impact mood, reduce depressive symptoms, and enhance various cognitive functions. They highlight the ability of music to evoke emotions and memories, providing a meaningful avenue for individuals with AD to connect with their identity. The review explains three plausible neural mechanisms underlying the positive effects of music interventions, including neurogenesis stimulation, dopamine release, and modulation of inflammatory processes. The authors conclude by introducing the ongoing Alzheimer's and Music Therapy Study (ALMUTH), which seeks to deepen our understanding of the influence of MT on brain aging, cognition, and mood in those at risk for AD.

Art therapy utilizes artistic activities such as painting, drawing, and sculpture to promote self-expression, improve mood, and enhance communication for individuals with Alzheimer's (Beard et al., 2012). Art therapy, recognized as a non-pharmacological complementary treatment, demonstrates clinical efficacy in mental disorders. The study by Hu et al., (2021), based at Shenzhen Technology University and Guangzhou University of Chinese Medicine, systematically explores art therapy's...
theoretical basis, clinical applications, and prospects through a PubMed search. Focusing on painting and drawing as therapeutic media, the review of 413 articles reveals positive outcomes in mental disorders, including depression, anxiety, cognitive impairment, dementia, AD, schizophrenia, and autism. Art therapy emerges as a valuable method for patients to express emotions and as an adjunct diagnostic tool for medical specialists, suggesting substantial potential for further exploration in clinical applications.

Pet therapy involves interactions with trained animals, such as dogs or cats, to provide comfort, reduce anxiety, and improve social engagement in individuals with Alzheimer's (Filan et al. 2006). A seven-year retrospective study spanning 2012 to 2019 by (Santaniello et al. 2020) investigated the impact of Animal-Assisted Therapy (AAT) on 127 mild-to-moderate AD patients. The participants were divided into three groups: an AAT group receiving interventions adapted to Reality Orientation Therapy (ROT), a ROT-only group, and a control group. Weekly sessions over six months showed significant improvement in cognitive function (assessed by Mini-Mental State Examination) and reduction in depressive states (evaluated by Geriatric Depression Scale) in the AAT group compared to ROT and control groups. The study highlights the potential of AAT, particularly in enhancing cognitive deficits associated with AD.

3.4. Physical Well-being

Exercise and physical activity interventions promote physical fitness and mobility, improve cognitive function, and reduce behavioral symptoms in individuals with Alzheimer's (Groot et al. 2016). In the article, Jia et al. (2019), explore the cognitive effects of physical activity and exercise on AD patients. The study, comprising 13 randomized controlled trials with 673 subjects diagnosed with AD, reveals a statistically significant improvement in cognition, as measured by the Mini-Mental State Examination (MMSE) score, in intervention groups compared to control groups. The study underscores the positive impact of physical activity and exercise on cognition in older adults with AD, emphasizing the need for further rigorous research to establish optimal intervention parameters.

3.5. Mindfulness and Mental Health

Mindfulness and meditation cultivate present-moment awareness and promote relaxation and emotional well-being in individuals with Alzheimer's (Wells et al., 2019). The systematic review by Chen et al. (2020), outlines an investigation into the potential efficacy of meditation for AD and mild cognitive impairment (MCI). The study conducts a comprehensive search of databases up to March 2020, including randomized controlled trials (RCTs) evaluating meditation interventions for AD and MCI patients. The primary outcomes focus on cognitive measures, including the Mini-Mental State Examination (MMSE), and the study aims to provide high-quality evidence on the effectiveness and safety of meditation as an intervention for cognitive impairment among AD and MCI patients.

3.6. Communication Support and Personal Interventions

Assistive communication devices include technologies such as speech-generating devices and picture-based communication aids to support individuals with Alzheimer's in expressing their needs and preferences (Bourgeois et al., 2009). The study by Gulapalli et al. (2022), explores non-invasive techniques for AD detection, focusing on speech features analyzed through ML classifiers. Traditionally, AD diagnosis relies on brain medical images, but the authors suggest that spontaneous speech (SS) features, including vocal, linguistic, acoustic, and prosodic aspects, could offer an early diagnosis. The article discusses various classifiers and ML algorithms applicable to AD detection, comparing their performance accuracies. The models, developed on diverse datasets, aim to contribute to the advancement of reliable machine assistive technology for healthcare in elderly populations, addressing conditions like AD, PD, vascular dementia, down syndrome, and frontotemporal dementia.

Personalized memoirs that compile photographs, mementos, and written narratives evoke memories and stimulate conversation in individuals with Alzheimer's (Dempsey et al., 2014). The authors Hashim et al. (2013), explore using a personalized digital memory book for reminiscence therapy in AD patients. Integrating multimedia and computer technology, the digital memory book discussed in the article caters to a 67-year-old early-stage Alzheimer's patient, offering information about the patient's family and a multimedia-based guide on performing prayers. The positive response from the patient suggests the effectiveness of this approach. The study advocates further research to enhance content, user interface design, and hardware, highlighting the potential of personalized digital memory books in AD therapy.

3.7. Environmental and Caregiver Support

Environmental modifications involve adapting to the living environment by removing hazards, providing clear signage, and using cues to support independence and safety for individuals with Alzheimer's (Gitlin et al., 2001). The paper by Ludden et al. (2019) addresses the urgent societal challenge of dementia by proposing a multidisciplinary approach to environmental design for dementia care. While various disciplines have contributed insights, integration is needed to ensure optimal design. The authors conduct a meta-review of recent studies in assistive technology for dementia care and healing environments. They advocate for a user-centered design approach combining meaningful sensory experiences and social engagement through technology-inspired design. Case studies of technology-enhanced prototypes, such as an experienced handrail and a virtual nature installation, demonstrate positive outcomes, emphasizing the potential of this integrated design approach to enhance the well-being of people with dementia and offer novel solutions to their daily challenges.

Caregiver support and training programs provide education, skills, and resources to caregivers of individuals with Alzheimer's to manage the challenges associated with caregiving (Brodaty et al., 2009). For a randomized controlled study,
Birkenhäuser-Gillesse et al. (2020), assessed the effectiveness of an Australian multicomponent community-based training program adapted for non-medical Dutch healthcare settings. Involving 142 caregiver-patient dyads, the study compared control and intervention groups. While the primary outcome, care-related quality of life, showed no significant difference, caregivers in the intervention group experienced fewer role limitations due to physical and emotional functions and pain reduction. Qualitative analysis revealed positive outcomes, including enhanced acceptance, coping, and improved knowledge of dementia and available community services. This study suggests that while quantitative impacts on care-related quality of life may be limited, qualitative benefits and specific improvements for caregivers are noteworthy. The authors, Pasquini et al. (2022), explained that a randomized controlled trial (RCT) assesses the impact of a psychosocial intervention on informal caregivers of Alzheimer's patients compared to traditional self-help groups. The study aims to analyze caregiver burden, coping strategies, and well-being, anticipating that the psychosocial intervention group will show more significant improvements.

<table>
<thead>
<tr>
<th>#</th>
<th>Intervention Technique</th>
<th>Benefits</th>
<th>Challenges</th>
<th>Reference</th>
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<tbody>
<tr>
<td>1</td>
<td>Cognitive Stimulation</td>
<td>Enhancing cognitive function and increased memory among older adults with Alzheimer's disease</td>
<td>Limited long-term effects, individual variability in response, need for trained facilitators</td>
<td>Wang et al. (2022)</td>
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<tr>
<td>2</td>
<td>Reality Orientation</td>
<td>Valuable non-drug therapy offering potential cognitive and emotional benefits</td>
<td>Limited evidence of long-term effects may cause frustration in some individuals</td>
<td>Li et al. (2023)</td>
</tr>
<tr>
<td>3</td>
<td>Validation Therapy</td>
<td>Improved the accuracy of differential diagnosis and prognostic prediction</td>
<td>Controversial approach, with the potential for reinforcing delusions or false beliefs, requires trained therapists</td>
<td>Kasula (2023)</td>
</tr>
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<td>4</td>
<td>Reminiscence Therapy</td>
<td>Improved mood, enhanced sense of identity, increased social interaction</td>
<td>Variability in response, potential for emotional distress in some individuals, limited evidence of long-term effects</td>
<td>Woods et al. (2018)</td>
</tr>
<tr>
<td>5</td>
<td>Assistive Technologies</td>
<td>Enhanced independence, improved safety, support in daily tasks and routines</td>
<td>Technological complexity, cost considerations, limited accessibility for some individuals</td>
<td>Ienca et al. (2017)</td>
</tr>
<tr>
<td>6</td>
<td>Electronic Memory Aids</td>
<td>Improved memory and task management, enhanced independence, and daily functioning</td>
<td>Technological challenges, difficulty in learning and adapting to new devices, potential reliance on external devices</td>
<td>Marziali et al. (2011)</td>
</tr>
<tr>
<td>7</td>
<td>Communication Apps and Devices</td>
<td>Enhanced communication and expression of needs, improved social interaction</td>
<td>Technological complexity, limited customization options, potential difficulties in learning and using new devices</td>
<td>Ekström et al. (2017)</td>
</tr>
<tr>
<td>8</td>
<td>GPS Tracking Devices</td>
<td>Enhanced safety, GPS tracking devices offer promising avenues for remote monitoring</td>
<td>Privacy concerns, ethical considerations, potential challenges in device usability and acceptance</td>
<td>Muurling et al. (2021)</td>
</tr>
</tbody>
</table>

Table 1 Conventional AD Intervention Techniques

Vol. XX Iss. XX yyyy
| 9 | Ambient Assisted Living | Implementation of sensor-based systems and smart home technologies to support individuals with dementia | Show promise in effectively assessing and supporting patients with mild cognitive impairment | Cost considerations, privacy concerns, integration with existing infrastructure | Herzog (2023) |
| 10 | Virtual Reality (VR) | Immersive and interactive experiences using virtual reality technology | Cognitive stimulation, reminiscence, relaxation, improved well-being and mood | Equipment cost, technical expertise requirements, potential for sensory overload | Garcia-Betances et al. (2015) |
| 11 | Music Therapy | Engagement in musical activities, listening to personalized playlists, and singing familiar songs | Improved mood, reduced agitation, enhanced emotional well-being | Individual preferences and response, challenges in delivering personalized therapy, limited evidence of long-term effects | McDermott et al. (2013) |
| 12 | Art Therapy | Engagement in artistic activities such as painting, drawing, and sculpture | Enhanced self-expression, improved mood, increased communication and social interaction | Individual variability in response, challenges in adapting to physical limitations, potential for frustration or difficulties in artistic expression | Beard et al. (2012) |
| 13 | Pet Therapy | Interaction with trained animals such as dogs or cats | The valuable non-pharmacological approach in Alzheimer's disease, providing positive outcomes, as revealed in a retrospective | Allergies or fears of animals, infection control considerations, limitations in facility settings | Santaniello et al. (2020) |
| 14 | Sensory Stimulation | Use of various sensory stimuli such as touch, smell, and sound to engage the senses | Enhanced cognitive function, increased relaxation, reduced agitation and restlessness | Individual response variations, sensory overload concerns, challenges in tailoring stimulation to personal preferences and needs | Hayden et al. (2022) |
| 15 | Exercise and Physical Activity | Regular engagement in physical exercise and activities | Improved cardiovascular health, enhanced cognitive function, reduced behavioral symptoms | Individual physical limitations, adherence challenges, need for tailored exercise programs | Groot et al. (2016) |
| 16 | Mindfulness and Meditation | Practice of mindfulness techniques and meditation | Reduced stress and anxiety, improved emotional well-being, increased self-awareness | Individual readiness and acceptance, challenges in maintaining regular practice, potential difficulty in individuals with cognitive impairments | Wells et al. (2019) |
| 17 | Assistive Communication Devices | Use of speech-generating devices and picture-based communication aids | Enhanced communication and expression of needs, increased social interaction | Learning curve for individuals with cognitive impairments, customization for individual needs, potential barriers in device acceptance | Bourgeois et al. (2009) |
18 Personalized Reminiscence Books
Creation of customized memory books with photographs and narratives
Stimulates memories and conversation, enhances sense of identity and self-expression
Challenges in creating and maintaining personalized books, individual preferences in reminiscence materials
Dempsey et al. (2014)

19 Environmental Modifications
Adaptation of the living environment to support independence and safety
Improved safety, reduced confusion, enhanced independence
Cost considerations, limited applicability in shared or institutional settings, individual variations in environmental preferences
Gitlin et al. (2001)

20 Caregiver Support and Training
Education and training programs for caregivers of individuals with Alzheimer's
Good psychosocial intervention, providing valuable support and training for informal caregivers of older individuals with Alzheimer's disease
Access to support programs, time and resource constraints, caregiver resistance or lack of awareness
Pasquini et al. (2022)

Table 1 compares various conventional intervention techniques for Alzheimer's disease. It includes the names of the methods, a brief description of their techniques, the benefits they offer, the challenges associated with their implementation.

Table 2 Hypothetical representation of the usage ratios for each intervention technique across different age groups (50-60, 60-70, and 70-80)

<table>
<thead>
<tr>
<th>#</th>
<th>Intervention Techniques</th>
<th>Age Group 50-60 (%)</th>
<th>Age Group 60-70 (%)</th>
<th>Age Group 70-80 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cognitive Stimulation</td>
<td>25</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Reality Orientation</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>Validation Therapy</td>
<td>5</td>
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<td>4</td>
<td>Reminiscence Therapy</td>
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<td>5</td>
<td>Assistive Technologies</td>
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<td>6</td>
<td>Electronic Memory Aids</td>
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<td>7</td>
<td>Communication Apps and Devices</td>
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<td>8</td>
<td>GPS Tracking Devices</td>
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<td>9</td>
<td>Ambient Assisted Living</td>
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<td>10</td>
<td>Virtual Reality (VR)</td>
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<td>11</td>
<td>Music Therapy</td>
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<td>Art Therapy</td>
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<td>13</td>
<td>Pet Therapy</td>
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<td>Sensory Stimulation</td>
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<td>15</td>
<td>Exercise and Physical Activity</td>
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<td>16</td>
<td>Mindfulness and Meditation</td>
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<td>17</td>
<td>Assistive Communication Devices</td>
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<td>Personalized Reminiscence Books</td>
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<td>Environmental Modifications</td>
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<td>20</td>
<td>Caregiver Support and Training</td>
<td>30</td>
<td>35</td>
<td>40</td>
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</tbody>
</table>

Table 2 represents the usage ratio of different intervention techniques for three age groups: 50-60, 60-70, and 70-80. The usage ratio indicates the percentage of individuals within each age group who utilize a particular intervention technique for managing Alzheimer's disease. In the age group 50-60, the most used techniques are Cognitive Stimulation (25%), Assistive
Technologies (35%), Electronic Memory Aids (30%), and Communication Apps and Devices (40%). These individuals rely more on technology-based interventions to support cognitive function and daily tasks. In the age group 60-70, there is an increased usage of techniques such as Reality Orientation (20%), Reminiscence Therapy (30%), Communication Apps and Devices (30%), and Exercise and Physical Activity (35%). These individuals benefit from interventions that focus on memory stimulation, social interaction, and physical well-being. In the age group 70-80, the usage ratio of techniques such as Reminiscence Therapy (35%), Assistive Technologies (30%), Exercise and Physical Activity (40%), and Mindfulness and Meditation (25%) is relatively higher. These individuals may require interventions that promote memory recall, physical health, and emotional well-being. It is important to note that the usage ratios provided in the table are illustrative and may vary depending on individual preferences, healthcare access, and other factors. The table offers a snapshot of the relative popularity of different intervention techniques across various age groups in managing AD. Figure 3 shows a pictorial representation of table 2.

Figure 3: Conventional Intervention Techniques Usage Ratio across Age Groups

4. Cutting-Edge Technological Intervention Approaches

Cutting-edge technological interventions in healthcare are witnessing a transformative shift with the integration of advanced technologies such as DL, ML, Vision Transformers (ViT), and Natural Language Processing (NLP). These innovative approaches hold significant promise in enhancing our understanding and management of neurodegenerative disorders, particularly Alzheimer's disease. Leveraging DL and ML aims to improve diagnostics, treatment, and patient care. Incorporating ViT and NLP further extends the capabilities, enabling comprehensive analysis of multimodal data and facilitating a more understanding of complex cognitive conditions. This amalgamation of state-of-the-art technologies represents a frontier in healthcare, offering unprecedented opportunities for early detection, precise intervention, and optimized outcomes for individuals affected by neurodegenerative disorders. This section explores advanced technologies such as DL, ViT, NLP, and ML techniques for intervention approaches in Alzheimer's disease, as shown in Figure 4.

DL is a subset of ML that utilizes artificial neural networks with multiple layers to learn and extract complex patterns from data. It has shown promising results in various domains, including healthcare and AD research. DL algorithms can analyze large amounts of medical data, such as brain images or genetic sequences, to aid in diagnosis, disease progression monitoring, and treatment prediction (LeCun et al. 2015). The authors Sharma et al., (2020), introduce the DL-based Internet of Health Framework for the Assistance of Alzheimer Patients (DeTrAs), a novel healthcare framework leveraging DL and IoT for personalized assistance to Alzheimer patients. In three phases, it predicts Alzheimer's using a recurrent neural network on sensory data, evaluates abnormality with CNN-based emotion detection and timestamp window-based NL processing and provides IoT-
based assistance. The results indicate a significant 10–20% improvement in accuracy over existing ML algorithms. The authors show that deeper training with multiple neural network layers contributes to DeTrAs' superior performance. The paper suggests future enhancements, including ambient intelligence and game theoretic approaches for achieving promising further advancements in Alzheimer's patient care within the Internet of Health ecosystem. Another study proposes (Guo et al., 2020) an Improved Deep Learning Algorithm (IDLA) for the early detection of AD using resting-state functional MRI (R-fMRI) data. The IDLA distinguishes natural aging from disorder progression by utilizing autoencoder networks and clinical text information. IDLA significantly enhances accuracy compared to conventional classifiers, reducing standard deviation by 45%. Incorporating R-fMRI data, the algorithm proves more reliable, providing a promising avenue for early Alzheimer's diagnosis and prevention. The research emphasizes the potential of DL in healthcare and highlights the benefits of improved algorithms in handling high-dimensional information. The paper by Zhao et al. (2023), explores DL integration in PET/MR imaging for Alzheimer's disease. The study highlights DL's potential in image segmentation, reconstruction, diagnosis, and visualization, and it outlines current applications, challenges, and prospects for enhanced AD diagnosis and personalized medicine.

![Figure 4: Cutting-Edge Technological Intervention Approaches](image)

Vision transformers are a DL model with significant success in computer vision tasks. They use self-attention mechanisms to capture relationships between image patches and learn representations directly from raw image data. ViT has been applied to various medical imaging tasks, including the analysis of brain MRI scans, to identify disease-related patterns and aid in diagnosis (Dosovitskiy et al. 2021). The paper by Xing et al. (2022), introduces ADVIT, a novel model designed for AD diagnosis using multimodal Positron Emission Tomography (PET) images. Departing from conventional CNN architectures, the model employs ViT as the backbone for enhanced feature extraction. Integrating PET-AV45 and PET-FDG modalities, the model addresses the computational challenges of 3D images through a 3D-to-2D conversion. Evaluation of the ADNI dataset demonstrates its superiority over baseline models, achieving an accuracy of 0.91 and an AUC of 0.95. The study emphasizes the effectiveness of ViT in medical imaging, underscores the advantages of multimodal input, and introduces a 3D-to-2D module for streamlined processing in the context of AD diagnosis. The authors (Odusami et al., 2023) discuss a pixel-level fusion approach leveraging ViT for early AD. Utilizing multimodal neuroimaging data from magnetic resonance imaging (MRI) and PET, the proposed model employs discrete wavelet transform (DWT) for data fusion and analysis. Transfer learning via a pre-trained VGG16 neural network optimizes the DWT technique. Fused images are then classified using a pre-trained vision transformer. Evaluation of the AD Neuroimaging Initiative (ADNI) dataset reveals an accuracy of 81.25% for AD/EMCI and AD/LMCI in MRI data and 93.75% for PET data. The ViT model demonstrates superior performance, outperforming existing studies, particularly achieving 93.75% accuracy on PET data. The proposed model offers a promising approach for classifying AD stages, showcasing its potential in real-world applications, and reducing the need for separate models for different imaging modalities. Further research avenues include exploring additional imaging modalities and visualization techniques.

NLP uses ML and linguistic techniques to analyze and understand human language. In Alzheimer's disease, NLP extracts meaningful information from medical records, patient interviews, and research papers. It enables automated processing of textual data for tasks such as sentiment analysis, information extraction, and language generation. (Bird et al. 2009). The systematic review by Ševčík, et al. (2022), explores AD detection through speech and NLP, focusing on datasets and participant characteristics. Utilizing databases like Scopus and Web of Science, they analyzed 37 studies from 2019 onward. Prominent
datasets included ADReSS, PITT, and CCC, with participant numbers ranging from 30 to 865. While dataset size was a factor, overall quality proved more crucial. Factors like age, gender, and education years emerged as significant indicators for Alzheimer's prediction. The review identifies areas for future research, emphasizing algorithm effectiveness in AD classification and progression prediction. The study by Mirzaei (2022), assesses the documentation of cognitive tests and biomarkers in electronic health records (EHRs) for AD and related dementia. Employing a rule-based NLP technique, the authors extracted and harmonized cognitive test scores from clinical narratives in a cohort of 48,912 AD/ADRD patients. Despite low documentation, the NLP pipeline demonstrated accuracy with an F1-score of 0.9059. The study highlights the potential of real-world data for AD/ADRD research, emphasizing the need for standardized approaches for cognitive tests and biomarkers.

ML techniques encompass a broad range of algorithms and methods that enable computers to learn patterns and make predictions from data without being explicitly programmed. These techniques, including decision trees, support vector machines (SVMs), and random forests (RF), can be applied to various aspects of AD research, such as predicting treatment response, identifying risk factors, and classifying disease subtypes (Hastie et al. 2009). The paper by Mirzaei et al. (2022), explores ML techniques for diagnosing AD and related disorders. Various approaches, including SVM, RF, CNN, and K-means, were covered in the review of articles published since 2016. The study emphasizes the challenge of early AD detection due to the absence of precise biomarkers and the high failure rate in clinical trials. DL techniques, especially CNNs, appear promising, leveraging transfer learning for improved diagnostic accuracy. Ongoing research aims to refine and enhance efficient AD diagnosis and prediction approaches. The paper (Chen et al. 2023) explores the classification of AD using ML techniques. Six algorithms, including KNN, decision tree, rule induction, Naïve Bayes, generalized linear model (GLM), and DL, were applied to the ADNI dataset. The GLM achieved an accuracy of 88.24% in classifying AD stages. The study emphasizes the significance of early detection and classification for tailored treatment. Improving healthcare resources, particularly electronic health records, can enhance data accessibility. The findings highlight the potential of ML in healthcare for disease detection and diagnosis. Future work could focus on improving classification accuracy, especially for certain AD stages with overlapping attributes.

Predictive modeling involves building mathematical models that predict future outcomes based on historical data. In AD, predictive modeling is utilized to predict the progression of the disease, estimate the probability of developing dementia, or forecast the reaction to a specific treatment. These models leverage ML algorithms to learn from available data and make accurate predictions (James et al. 2013). The study by Moscoso et al. (2019), investigates MRI's efficacy in predicting AD dementia over five years. Key findings include enhanced specificity (71%) and discriminative power (84% AUC) with extended follow-up, challenging the reliance on short-term data for ML algorithms. The research underscores the significance of prolonged follow-up for refining predictive models and ensuring robust performance. The authors Park et al. (2020) present a predictive model for AD, integrating extensive gene expression and DNA methylation data. The research uses a novel feature selection method and deep neural network-based predictive model to address high-dimensional, low-sample-size data issues. Results reveal superior performance to conventional ML algorithms, emphasizing the enhanced accuracy of multimics data integration. The proposed methodology holds promise for advancing AD diagnosis and prediction, contributing to understanding the disease's molecular mechanisms.

Data mining and pattern recognition involve extracting valuable insights and identifying patterns from large datasets. In Alzheimer's disease, several methods are used to explore different types of data, such as neuroimaging data, genetic information, and clinical records. By doing so, these methods can uncover hidden correlations, biomarkers, and disease patterns. This can help identify the disease early, diagnose it, and design personalized treatment plans (Han et al., 2011). The Buyukoglu (2021) study narrates early AD detection using ensemble feature selection approaches and data mining techniques. Focusing on Normal, Mild Cognitive Impairment (MCI), and AD classes, both homogeneous and heterogeneous ensemble methods are applied. Feature subsets generated through these approaches are utilized in a predictive model employing RF, Artificial Neural Network, Logistic Regression, SVM and Naïve Bayes data mining algorithms. Comparative analysis indicates superior performance, with the RF algorithm outperforming, achieving a 91% accuracy when applied to the feature subset obtained through the heterogeneous ensemble feature selection approach. The article (Lazli et al., 2020) investigates computer-aided diagnosis (CAD) systems for brain disorders, notably AD. The CAD system, a synergy of ML and neuroradiology, enables swift diagnoses and emphasizes early AD detection through neuropsychological assessments. By fusing data from various imaging modalities, the CAD system enhances the quality of MRI scans, making them more reliable for clinical use. The article explains the steps involved in CAD, reviews research related to Alzheimer's disease, and explores methods for classifying and segmenting brain regions. The article proposes a multimodal fusion approach and conducts a performance study comparing the accuracy of multimodal and single MRI modality CAD systems, focusing on pattern recognition. The discussion highlights the advancements in information fusion in medical imaging and advocates for hybrid models in the diagnosis of brain diseases.

Image analysis techniques involve quantitatively analyzing medical images, such as MRI or PET scans, to assess disease progression in Alzheimer's patients. ML algorithms are applied to extract relevant features, detect abnormalities, track changes in brain structures over time, understand disease progression patterns, and develop effective treatment strategies (Vrooman et al., 2007). Zhang et al. (2021) proposed the Consensus Multi-view Clustering (CMC) model, leveraging non-negative matrix factorization (NMF) for predicting AD progression stages. CMC integrates multi-view data, automatically learning a unified representation. This novel model mitigates the need for manual parameter settings in multi-view fusion, enhancing clustering accuracy. The study employs brain MRI datasets, utilizing image processing techniques such as SIFT, KAZE, and Gabor filter to create twelve views. Results demonstrate CMC's superior performance over baselines, highlighting its potential for aiding medical diagnosis and detection of AD stages through advanced image processing methodologies. The paper concludes with...
insights into related work, the proposed model's methodology, optimization algorithms, experimental findings, and future directions. Another study by Ghazi et al. (2019), introduces an innovative Long Short-Term Memory (LSTM) algorithm, revolutionizing AD progression modeling by overcoming challenges posed by incomplete data. The proposed LSTM applied to ADNI cohort MRI biomarkers, outperforms traditional imputation-dependent methods, significantly reducing mean absolute error. Noteworthy contributions include a novel back propagation through time formulation, accommodating missing values, and modeling temporal dependencies. With a three-fold impact, encompassing multidimensional sequence learning, the paper establishes an end-to-end approach for robust neurodegenerative disease modeling, ensuring LSTM's robustness and statistical significance across diverse scenarios.

Genomic analysis involves studying the genetic makeup of individuals to identify genetic variants associated with AD. ML techniques are used to analyze genomic data, like DNA sequences and gene expression profiles, by employing related genetic markers and pathways. This knowledge can contribute to personalized treatment approaches and drug discovery (Ridge et al., 2013). Li et al. 2021 review focuses on AD genomics, spotlighting over 130 susceptible and rare variants linked to APOE, TREM2, CR1, and more. Aging's pivotal role in late-onset AD is explored through somatic mutations in AD patients. The findings underscore innate and adaptive immunity's involvement, emphasizing the systemic failure of cell-mediated amyloid-β clearance in AD progression. Enriching AD-associated variants in myeloid-specific regulatory regions hints at perturbed gene expression affecting Aβ clearance. The emerging paradigm proposes leveraging immunotherapy to boost innate immune functions, potentially modulating AD progression at asymptomatic stages. This genome-wide meta-analysis on AD reveals 29 risk loci and 215 potential causative genes, shedding light on the highly heritable nature of AD. Another study by Jansen et al. (2019), encompassing 71,880 cases and 383,378 controls, emphasizes strong genetic correlations with immune-related tissues and cell types. Implicated genes prominently in the spleen, liver, and microglia, with identified biological mechanisms involving lipid-related processes and amyloid precursor protein degradation. The findings establish connections with various health-related outcomes and suggest a protective role of cognitive ability against AD risk, advancing our understanding of the genetic factors influencing AD susceptibility.

Data fusion involves integrating and combining heterogeneous data from multiple sources to gain a comprehensive understanding of AD. ML techniques can fuse data from various modalities, such as neuroimaging, genetics, clinical assessments, and lifestyle factors. It can provide a holistic view of the disease and facilitate more accurate diagnosis and treatment decisions (Faisal et al. 2014). This study, by Arco et al. (2021), introduces a novel data fusion system for early AD detection by combining MRI and neuropsychological tests. The model utilizes a Searchlight strategy and Support-Vector Machine classifiers and achieves a maximum accuracy of 80.9%. The Searchlight approach identifies informative brain regions during different stages of the longitudinal study, offering insights into AD development. The system is robust across sessions, avoiding bias from brain atlases, and holds the potential for broader neurological disorder diagnosis. Another study by Abrol et al. (2019), introduces a multimodal data fusion framework, combining deep residual learning of structural MRI (sMRI) features and dynamic functional connectivity (DFC) features from functional MRI (fMRI) for predicting AD progression. Cross-validated results reveal a significant performance improvement over unimodal analyses, with p-values of 7.03 x 10^-7 for fMRI and 6.72 x 10^-4 for sMRI. The study underscores the value of integrating diverse neuroimaging modalities through data fusion, showcasing the efficacy of DL and dynamic functional connectivity features in predicting AD progression. The paper by Krokidis et al.( 2023) addresses the lack of comprehensive AD single-cell RNA sequencing (scRNA-seq) analysis. The proposed computational workflow identifies potential genetic signatures from peripheral blood cells, offering a promising avenue for uncovering blood-based biomarkers and understanding AD pathophysiology at the molecular level.

Early detection and diagnosis of AD are crucial for timely intervention and management. ML techniques can be employed to analyze various types of data, such as cognitive assessments, biomarkers, neuroimaging, and genetic information, to develop predictive models that can identify individuals at risk or in the early stages of the disease. Early detection facilitates early intervention and improves patient outcomes (Mormino et al., 2014). Clinical practice in diagnosing early AD emphasizes the importance of early detection for effective management. Alzheimer's progression, from preclinical stages to dementia, necessitates timely identification for planning and lifestyle adjustments. Challenges in early diagnosis include time constraints, diagnostic accuracy, and overlooking symptoms as part of aging. The evolving diagnostic model calls for interdisciplinary care integration, starting with primary care. A review by Porsteinsson et al. 2021, underscores the shift toward early Alzheimer's diagnosis, offering practical guidance and tools for healthcare providers. The multidisciplinary approach ensures timely detection, assessment, and management, aligning with emerging therapeutic prospects for early intervention in AD. The study by Murugan et al. (2021), the DL Model for Early Diagnosis of Alzheimer's Diseases and Dementia (DEMNET), a CNN, is proposed for efficient classification using MRI images recognizing the crucial stages of AD progression and lack of methods with consistent precision. DEMNET addresses class imbalance issues and outperforms with an accuracy of 95.23%, AUC of 97%, and Cohen’s Kappa of 0.93%. Demonstrating robustness, the model achieved an accuracy of 84.83% when tested on ADNI datasets. Future work includes training DEMNET on diverse datasets, utilizing advanced classifiers, and optimizing overall performance.

Digital biomarkers refer to objective and quantifiable measures of physiological, behavioral, or cognitive characteristics collected using digital devices. ML techniques can analyze data from wearables, smartphones, or other digital tools to derive meaningful biomarkers for AD. Digital biomarkers offer the potential for continuous monitoring, early detection, and personalized interventions. By examining early AD manifestations and utilizing biomarkers from sensor and mobile/wearable devices, (Kourtis et al. 2019). The article by Kourtis et al. 2019, emphasizes the pivotal role of digital biomarkers amid the escalating healthcare burden of AD. Cognitive, sensory, and motor changes preceding clinical manifestations pose diagnostic challenges, prompting the exploration of consumer-grade mobile and wearable technologies for accessible biomarkers. As AD
care costs surge, the urgent development of technologies for early detection and continuous monitoring becomes paramount. Envisaging routine digital phenotyping, potential responses to signal detection, and the establishment of personalized baseline references in clinical trials amplify the significance. The study, led by Harms et al. (2022), explores the intersection of digital biomarkers and sex impacts in AD management, emphasizing a potential shift toward innovative medicine. Digital biomarkers, measured by devices, enable high-frequency, longitudinal, and sensitive measurements, particularly in neurodegenerative diseases. The study focuses on sex differences in Altoida's digital medical application, revealing distinct neurocognitive performance signatures between males and females. Notably, these differences may be disease-stage dependent. The findings identify the need to integrate digital biomarker technologies into traditional dementia research for precise diagnostics, targeted prevention, and customized AD treatment, considering sex-specific risk profiles and diagnostic tool adjustments.

Explainable AI techniques aim to provide transparent and interpretable models and insights. In the context of AD, Figure 5 implicates how explainable AI methods can help clinicians and researchers understand the underlying factors and features that contribute to disease prediction, treatment response, or diagnostic decisions. Explainable AI helps foster trust in the ML models and enables effective decision-making (Caruan et al. 2015). The article by Viswan et al. 2023 systematically reviews the application of Explainable Artificial Intelligence (XAI) in AD classification. Acknowledging the limited acceptance of AI models in medical diagnosis due to their black-box nature, the study focuses on XAI methods employed in AD prediction over the past decade. Following PRISMA guidelines, the review categorizes AI models based on various XAI methods and frameworks, providing a comprehensive spectrum from intrinsic to complex interpretations. The study evaluates the merits of different interpretation forms, offering profound insights into factors supporting clinical AD diagnosis while addressing limitations and outlining open research challenges.

Another article by Sudar et al. (2022), explores AD identification through XAI using Layer-wise Relevance Propagation (LRP), VGG-16, and CNN. The study employs an Alzheimer's brain image dataset and XAI for trustworthy results. LRP, VGG-16, and CNN contribute to accurate predictions and feature explanations. Combining XAI and neural networks provides a trustworthy solution for Alzheimer's diagnosis. The study's transparency enhances interpretability, offering insights into the decision-making process. The paper by Holzinger et al. (2023) highlights the significant role of conceptual knowledge in advancing robust and explainable medical AI. The paper integrates three research areas namely complex networks, graph causal models, and verification and explainability, to unify research and practical applications. The paper also emphasizes the importance of ethical and legal considerations for trustworthy medical AI solutions.

These techniques show a wide range of applications in AD intervention, including DL, ViT, NLP, and ML. They hold great potential for improving diagnosis, treatment, and care for individuals with Alzheimer's and advancing our understanding of this complex neurodegenerative disease.

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Techniques</th>
<th>Beneﬁts</th>
<th>Challenges</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Deep Learning</td>
<td>Neural networks with multiple layers</td>
<td>Accuracy Prediction and automatic feature learning for early detection</td>
<td>Large data requirements, computationally intensive, black-box nature</td>
<td>Zhao et al. (2023)</td>
</tr>
<tr>
<td>Section</td>
<td>Topic</td>
<td>Description</td>
<td>Challenges</td>
<td>References</td>
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<tr>
<td>2 Vision Transformers</td>
<td>Attention-based transformer architecture for image processing</td>
<td>Effective in image recognition, attention mechanism for capturing global and local context</td>
<td>Limited interpretability, high computational cost, challenges in handling large images</td>
<td>Dosovitskiy et al. (2021)</td>
<td></td>
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<tr>
<td>4 ML Techniques</td>
<td>Various algorithms for pattern recognition and prediction</td>
<td>Versatile in different domains, automated decision-making, pattern discovery</td>
<td>Feature engineering, overfitting, bias in training data</td>
<td>Hastie et al. (2009)</td>
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<tr>
<td>5 Predictive Modeling</td>
<td>Statistical modeling and algorithms for prediction</td>
<td>The potential of translating predictive models into practical clinical applications through user research, adoption opportunities, and the conceptual design of a decision support tool, fostering more effective disease management.</td>
<td>Overfitting, model complexity, selection bias, data quality and preprocessing</td>
<td>Bellio's (2021)</td>
<td></td>
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<td>6 Data Mining and Pattern Recognition</td>
<td>Extracting knowledge from large datasets</td>
<td>Discover hidden patterns, identify associations, extract useful information</td>
<td>Data preprocessing, scalability, interpretability</td>
<td>Han et al. (2011)</td>
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<td>7 Image Analysis for Disease Progression</td>
<td>Analyzing medical images to track disease progression</td>
<td>Early detection, quantitative assessment, treatment monitoring</td>
<td>Image variability, accuracy and reproducibility, data preprocessing</td>
<td>Shen et al. (2007)</td>
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<tr>
<td>8 Genomic Analysis</td>
<td>Analyzing genomic data for insights into disease mechanisms</td>
<td>Identification of genetic markers, personalized medicine, understanding disease pathways</td>
<td>Data integration, interpretation of complex data, ethical considerations</td>
<td>Visscher et al. (2017)</td>
<td></td>
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<tr>
<td>9 Data Fusion</td>
<td>Integrating information from multiple sources</td>
<td>Data fusion in computational analysis promises to identify potential biomarkers for Alzheimer's Disease, offering insights into diagnostic and therapeutic advancements.</td>
<td>Data compatibility, integration methods, data quality and reliability</td>
<td>Krokidis et al. (2023)</td>
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<tr>
<td>10 Early Detection and Diagnosis</td>
<td>Identifying diseases at early stages</td>
<td>Early intervention, improved prognosis, better treatment outcomes</td>
<td>Sensitivity and specificity, false positives, access to early screening</td>
<td>Sardanelli &amp; Di Leo, G. (2012)</td>
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<td>11 Digital Biomarkers</td>
<td>Utilizing digital data to monitor health indicators</td>
<td>Non-invasive monitoring, real-time data collection, remote patient management</td>
<td>Data validity and reliability, regulatory considerations</td>
<td>Chan et al. (2019)</td>
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<td>12 Explainable AI</td>
<td>Interpreting and explaining AI model predictions</td>
<td>Fostering robust, explainable, and trustworthy outcomes in the realm of medical artificial intelligence.</td>
<td>Complexity of models, trade-off between interpretability and performance</td>
<td>Holzinger et al. (2022)</td>
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</table>
Table 3 compares various DL, ViT, NLP, and ML techniques. It highlights their respective techniques, benefits, challenges, and includes references for further exploration. The table provides a concise overview of these techniques and their relevance in the context of AD interventions.

Table 4 Hypothetical representation of the usage ratios for each intervention technique across different age groups (50-60, 60-70, and 70-80).

<table>
<thead>
<tr>
<th>#</th>
<th>Technique</th>
<th>Usage Ratio (50-60)</th>
<th>Usage Ratio (60-70)</th>
<th>Usage Ratio (70-80)</th>
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<td>2</td>
<td>Vision Transformers</td>
<td>0.3</td>
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<td>Natural Language Processing</td>
<td>0.7</td>
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<td>0.5</td>
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<td>ML Techniques</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
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<td>Predictive Modeling</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>Data Mining and Pattern Recognition</td>
<td>0.5</td>
<td>0.4</td>
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<td>Image Analysis for Disease Progress</td>
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<td>Genomic Analysis</td>
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<td>Data Fusion</td>
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<td>Early Detection and Diagnosis</td>
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<td>0.5</td>
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<td>Digital Biomarkers</td>
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<td>0.5</td>
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<td>12</td>
<td>Explainable AI</td>
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</tbody>
</table>

Figure 6: Cutting Edge Intervention Techniques Usage Ratio across Age Groups
The table 4 represents the usage ratio of various techniques in the field of DL, ViT, NLP, and ML among different age groups (50-60, 60-70, and 70-80). The usage ratio indicates the extent to which each technique is employed within each age group. Note that the usage ratios in the table are hypothetical and serve as an example. The actual usage ratios may vary depending on factors such as technological advancements, accessibility, and specific research or industry contexts. Figure 6 shows the pictorial representation of table 4. The usage ratio is represented as a decimal number ranging from 0 to 1, where 1 signifies a high adoption rate and 0 indicates a low adoption rate. For example, in the age group 50-60, the technique "DL" has a usage ratio of 0.6, implying that it is relatively more widely used in this age group compared to others. Similarly, the usage ratios for other techniques can be observed for each age group.

5. Findings and Discussion

From the results presented in the table, we can observe the utilization of both conventional intervention techniques and advanced technologies such as DL, ViT, NLP, and ML in AD intervention.

Conventional intervention techniques such as cognitive stimulation, reality orientation, validation therapy, reminiscence therapy, assistive technologies, electronic memory aids, communication apps and devices, GPS tracking devices, and ambient assisted living are still widely used in managing and supporting Alzheimer’s disease. These techniques provide various benefits, such as cognitive enhancement, improved communication, increased independence, and better quality of life for individuals with Alzheimer’s. However, they may also present challenges related to implementation, caregiver training, and individual responsiveness.

On the other hand, these advanced technologies offer promising avenues for AD intervention. For instance, DL techniques can analyze complex patterns and structures in data, enabling the development of predictive models and personalized treatment approaches. ViTs enable efficient and accurate analysis of medical images, facilitating image analysis for disease progression and computer-aided diagnosis. NLP techniques aid in understanding and extracting information from medical records, enabling disease subtyping and NLP for medical applications. Also, ML techniques, including predictive modeling and data mining, allow for identifying predictive biomarkers and discovering potential drug targets.

These advanced technologies provide benefits such as improved diagnosis accuracy, personalized treatment strategies, early detection, and longitudinal disease modeling. However, they also come with challenges related to data privacy and security, interpretability of AI models, patient acceptance and trust, integration with existing healthcare systems, technical challenges, regularity compliance, ethical considerations, interoperability, and workforce training and education, as shown in Figure 7.

![Figure 7: Challenges in implementing advanced technology in healthcare](image-url)

When comparing the traditional techniques for intervening in AD, such as cognitive stimulation and caregiver support, with innovative methods, such as DL and NLP, traditional approaches emphasize cognitive enhancement and social interaction but come with challenges, such as limited long-term effectiveness and the need for trained facilitators. On the other hand, advanced
technologies offer benefits such as improved diagnostic accuracy and personalized treatment strategies, but they face obstacles such as data privacy concerns and interpretability issues. By combining these approaches, we can achieve synergistic effects, addressing the limitations of each method. By examining this interplay, we can gain a more comprehensive understanding of AD intervention, which can inform future research to optimize techniques and develop personalized intervention strategies.

Integrating AI into AD interventions has raised several ethical concerns. The issues related to data privacy, algorithmic bias, and informed consent are crucial. Protecting patient data, mitigating bias, and ensuring transparent consent processes are essential. Healthcare professionals must navigate accountability while preserving the patient-provider relationship. Therefore, balancing AI's autonomy with human judgment is critical to ensuring ethical AD care.

6. Future Research

Future research in AD intervention techniques holds promise in several key areas. Long-term effectiveness and personalized response evaluation are crucial for understanding the impact of interventions on cognitive function and daily life. Interdisciplinary collaboration is essential for optimizing techniques and fostering communication networks. Remote monitoring using AI offers the potential for real-time assessment, while personalized intervention strategies driven by adaptive algorithms could greatly enhance treatment outcomes. Integrating multimodal data sources, usability testing, and user-centered design are crucial for accessibility and effectiveness, along with cost-effectiveness and scalability evaluations to understand resource implications.

Integrating technology with traditional therapies, optimizing multisensory stimulation, and enhancing caregiver support is pivotal for improving quality of life. Advanced fusion techniques for data integration, incorporating ambient intelligence and IoT, and addressing ethical and legal considerations are essential. Conducting real-world validation and longitudinal studies is crucial to evaluating a treatment or intervention's clinical usefulness and long-term effectiveness. Combining conventional intervention techniques and cutting-edge advanced technologies can significantly enhance AD intervention and support. It allows for a multidimensional approach that addresses the disease's cognitive, functional, and behavioral aspects while leveraging the power of data analysis and technological advancements. Future research and development in these areas promise to improve the quality of care and outcomes for individuals affected by AD.

7. Conclusion

The paper compares the conventional techniques used for AD intervention with advanced technologies like DL and NLP. While conventional methods offer benefits such as cognitive enhancement, they face challenges in implementation and caregiver training. Advanced technologies promise personalized treatment but encounter issues like data privacy and interpretability. Integrating these approaches can address their limitations and provide a more comprehensive AD intervention strategy. However, ethical concerns arise with AI integration. Balancing these techniques can optimize AD care and improve outcomes for affected individuals.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest in this work.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.
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