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A research landscape analysis on Alzheimer's disease and gerontechnology: Identifying key contributors, hotspots, and emerging trends

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ABSTRACT

This paper presents a systematic bibliometric analysis of the research landscape at the intersection of Alzheimer's disease and gerontechnology, identifying key contributors, research hotspots, and emerging trends. Utilizing data from Scopus and Web of Science, the study applies tools such as VOSviewer and ScientoPy to analyze co-authorship networks, keyword occurrences, and citation trends. The results reveal growing contributions from global regions, particularly the U.S., Italy, and China, with increasing emphasis on assistive technologies and artificial intelligence for early diagnosis. However, significant gaps exist, especially in studies addressing long-term effectiveness and inclusivity across demographic groups. This landscape analysis provides crucial insights to guide future research on integrating technology into Alzheimer's care, underscoring the importance of a patient-centered approach for sustainable solutions.

Introduction

The increasing prevalence of Alzheimer's disease (AD) represents one of the most pressing public health challenges globally. Currently affecting over 55 million individuals worldwide, this neurodegenerative disorder is characterized by progressive cognitive decline, impacting not only the patients but also their families and caregivers (Prince et al., 2015)). With global aging populations, the number of people affected by AD is expected to triple by 2050, making it a critical health concern that demands innovative, multifaceted approaches to care (Mansourian et al., 2021)Traditional care methods often fail to address the diverse and evolving needs of individuals with AD, thus necessitating the exploration of new interventions.

Gerontechnology, an interdisciplinary field focused on the application of technology to improve the quality of life for older adults, has emerged as a vital area of research in the context of Alzheimer's disease. Technologies such as smart home systems, wearable devices, and telehealth solutions are increasingly recognized for their potential to support cognitive health, enhance daily living, and alleviate caregiver burdens (Asiri et al., 2023; Javed et al., 2023; Lin et al., 2024)These technologies have demonstrated promise in promoting patient autonomy, reducing caregiver strain, and facilitating remote health monitoring (Shu & Woo, 2021; Yamazaki et al., 2020). However, despite the promising developments in gerontechnology, the current literature reveals significant gaps in systematic evaluations of these technologies, particularly concerning their long-term effectiveness and user acceptance(Martin et al., 2024).

A systematic review by Khoury & Ghossoub, (2019) discusses the potential of biomarkers for the early detection of Alzheimer's disease. Biomarker-based diagnostics have been a crucial step forward in early-stage intervention, yet there remains a lack of comprehensive analyses that integrate technological innovations with clinical practices. While numerous original studies have explored specific technologies or interventions, there is a scarcity of meta-analyses synthesizing findings across various studies to draw broader conclusions about the efficacy of gerontechnological solutions in Alzheimer's care (Martínez-Alcalá et al., 2016)

Furthermore, existing research often overlooks the diverse experiences and needs of different demographic groups, particularly underserved populations such as those in lower socioeconomic status or from diverse ethnic backgrounds (Shahar et al., 2019). This lack of inclusivity in research design limits the applicability of findings and hinders the development of universally accessible interventions (Azizan et al., 2023) Additionally, the intersectionality of technology, aging, and health

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disparities requires more nuanced exploration, as factors such as socioeconomic status, cultural background, and technological literacy can significantly influence technology adoption and effectiveness (Fang et al., 2022; Hand & Ihara, 2024)

This paper aims to conduct a systematic research landscape analysis of the literature on Alzheimer's disease and gerontechnology. By employing bibliometric methods to map the existing research, the study seeks to identify key contributors, research hotspots, and emerging topics within this dynamic field. Through this analysis, we aim to highlight current gaps in the literature, particularly the need for systematic reviews and meta-analyses that can provide comprehensive insights into the effectiveness and acceptance of gerontechnological interventions. Ultimately, this research will inform future inquiries, guiding the development of innovative, evidence-based solutions that can enhance the care and quality of life for individuals affected by Alzheimer's disease.

As the global prevalence of Alzheimer's disease continues to rise, innovative care models are increasingly incorporating gerontechnology to support both patients and caregivers. Despite promising advancements, the research landscape remains fragmented, lacking systematic reviews that explore the long-term effects of technological interventions (Nichols et al., 2022)

This paper employs bibliometric methods to consolidate key findings and chart emerging trends in the field, providing an essential overview of ongoing research gaps.

Materials and methods

The present research landscape analysis of Alzheimer's disease and gerontechnology was conducted using a systematic bibliometric approach to retrieve, process, and analyze relevant scholarly articles. The following methodology outlines the key steps taken to address the research questions, including article selection, data processing, and validation techniques.

Database selection

This study utilized Web of Science and Scopus for article retrieval due to their extensive indexing across disciplines and robust citation analysis tools. While we acknowledge that this selection may exclude important contributions from databases like PubMed, IEEE Xplore, and ACM Digital Library, the chosen databases were deemed sufficient for the bibliometric scope of this paper.

Research design

This study adopts a comprehensive research landscape analysis framework to examine the intersection of Alzheimer's disease and gerontechnology. Unlike traditional systematic or scoping reviews, this approach emphasizes both high-quality outcomes and the timely completion of the research process (Moher et al., 2016).The use of bibliometric analysis allows for a nuanced understanding of research trends, collaboration networks, and emerging themes (Azizan, 2024). In order to ensure robustness, we specifically utilized two widely respected databases, Web of Science (WoS) and Scopus, rather than aggregating data from numerous sources, as this streamlined approach enhances efficiency while maintaining a comprehensive view of the research landscape (Pranckutė, 2021)

To improve research rigor, we adopted a modified version of the conventional dual-reviewer model, delegating quality checks to a single researcher. This decision expedited the research process while maintaining integrity through repeated checks by an experienced reviewer (Johnson et al., 2020). Additionally, narrative synthesis was employed to summarize the findings, offering a clear overview without the complexity associated with meta-analyses(Cumpston et al., 2023).

Article retrieval from WoS and scopus

To map the research landscape, articles were retrieved from two major databases: Web of Science (WoS, n=51) and Scopus (n=85). These platforms were selected due to their extensive indexing practices, diverse disciplinary coverage, and strong reputations for high-quality content in health, social sciences, and technology fields (Azizan, 2024;).

- Web of Science (WoS): Known for its comprehensive citation tracking capabilities, WoS provides access to a range of journals, particularly those focusing on the intersection of gerontology and technological innovations (Birkle et al., 2020). Its citation indexing feature allows for an assessment of research impact over time.
- Scopus: As one of the largest abstract and citation databases, Scopus offers a broad scope of research outputs, including peer-reviewed journal articles and conference proceedings across medicine, technology, and social sciences. Scopus also includes advanced analytical tools that facilitate the assessment of research trends and author contributions, making it essential for a thorough bibliometric analysis .(Yubo et al., 2023)

The combination of these databases enabled a robust analysis by leveraging the unique strengths of both, providing a holistic view of the research landscape in Alzheimer's disease and gerontechnology.

Inclusion and exclusion criteria

To ensure focus and relevance, specific inclusion and exclusion criteria were applied. Articles had to be:

- Peer-reviewed research articles
- Written in English
- Published before August 31, 2024
- Focused on human populations and relevant technological interventions for Alzheimer's disease

Animal studies and articles not available in English were excluded, as they did not align with the primary focus of this study on human populations and relevant gerontechnological interventions (Azizan, 2024a)

Validation of search strategy

Three complementary validation methods were employed to ensure the accuracy and comprehensiveness of the search strategy:

Manual Review: A manual review of a sample of retrieved articles was conducted to verify their relevance and adherence to inclusion criteria. This step was crucial for refining search terms and ensuring that the retrieved literature aligned closely with the research objectives (Marshall & Wallace, 2019)

Comprehensive Evaluation: Retrieved articles were cross-referenced with key studies identified through established literature to assess the completeness of the search. This step confirmed that the search strategy effectively captured both recent publications and significant foundational research, thereby ensuring the reliability of the dataset (Bramer et al., 2018)

Expert Feedback: Feedback from subject matter experts in gerontology and technology was incorporated to refine keyword selection and validate search results. This collaboration enhanced the credibility of the research by ensuring that the strategy was aligned with the latest advancements in the field (Chen, 2020). Together, these validation methods ensured that the search strategy captured the majority of relevant articles, thereby enhancing the quality and relevance of the research.

Data pre-processing

Data pre-processing was carried out using ScientoPy, a Python library specifically designed for bibliometric analysis (Ruiz-Rosero et al., 2019). This tool facilitated the merging of datasets from Scopus and WoS, ensuring that duplicates were identified and removed. The clean dataset was subsequently visualized in VOSviewer, a software tool that constructs and visualizes bibliometric networks, including co-authorship networks, keyword co-occurrences, and citation relationships (Azizan & Fadzil, 2024). VOSviewer enabled a comprehensive view of research trends, allowing for the identification of key contributors and emerging topics within Alzheimer's disease and gerontechnology.

Ethical considerations

This study did not involve human subjects or the collection of personal data, and thus, ethical approval was not required. However, ethical standards were maintained by ensuring that all sources used in the analysis were properly cited and acknowledged.

Keywords used

The search strategy was constructed using Boolean logic and targeted the following terms:

Population (#1): Older adults with Alzheimer's disease, elderly individuals diagnosed with Alzheimer's, caregivers of Alzheimer's patients.

Interventions (#2): Gerontechnology interventions, assistive technologies for aging, smart home technologies, digital health solutions, wearable monitoring devices.

Comparison (#3): Standard care practices, traditional interventions, no intervention.

Outcome (#4): Cognitive function improvement, quality of life enhancement, reduction in caregiver burden, behavioral symptom management, overall health outcomes.

This structured approach ensured comprehensive retrieval of articles, aligning with the research focus on Alzheimer's disease and gerontechnology (Azizan, 2023).

SCOPUS (N=85) (TITLE ("Alzheimer's disease" OR "Alzheimer*") AND TITLE ("Gerontechnology" OR "Assistive technolog*" OR "smart home technology*" OR "wear* technology*" OR "technology*") AND TITLE-ABS-KEY ("cognitive*" OR "quality" OR "reduce*" OR "behavio*ral" OR "health*") AND TITLE-ABS-KEY ("old" OR "age*" OR "geriatric*" OR "elder*" OR "patient*")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English"))

WOS

(N=51) "Alzheimer's disease" OR "Alzheimer*" (Title) and "Gerontechnology" OR "Assistive technolog*" OR "smart home technology*" OR "wear* technology*" OR "technology*" (Title) and "cognitive*" OR "quality" OR "reduce*" OR "behavio*ral" OR "health*" (Topic) and "old" OR "age*" OR "geriatric*" OR "elder*" OR "patient*" (Topic) and Article or Review Article (Document Types) and English (Languages)

Interpreting VOSviewer maps and generating research topics

Keyword co-occurrence maps generated using VOSviewer were analyzed to visualize relationships between terms. Keywords are represented as nodes, with links indicating frequent co-occurrences, thereby forming clusters of related research themes. Larger nodes represent more prevalent topics in the literature. By analyzing these clusters, overarching topics and emerging trends were identified (van Eck & Waltman, 2014), such as the integration of assistive technologies into Alzheimer's care, artificial intelligence for early diagnosis, and caregiver support technologies. This approach allowed for the formulation of targeted research inquiries and identification of interdisciplinary research opportunities.

Results

Growth pattern, active countries, and active journals

The growth pattern of publications related to Alzheimer's disease and gerontechnology is illustrated in Fig. 1. The data reveals a gradual increase in total publications (TP) over the years, with notable fluctuations. Initially, from 1998 to 2003, the number of publications remained low, with only one publication recorded in 1998 and 2004 each. A significant uptick began in 2007, where the number of publications rose to two, followed by three in 2008, marking a turning point in scholarly output. The peak year for publications was 2021, with a total of 11 publications. This surge in 2021 was accompanied by an increase in citations (TC), which reached a high of 672 in 2012, indicating that the research output during this period was not only prolific but also impactful. The data suggests that there is a growing interest and engagement in the field, particularly between 2012 and 2015, where TP fluctuated between 5 and 9 publications annually.

Fig. 2 presents the distribution of research activity across countries, highlighting the top ten countries contributing to the literature on Alzheimer's disease and gerontechnology. The United States leads significantly with 37 total publications, followed by Italy with 16 and China with 14. Other notable contributors include Sweden and the United Kingdom, each with 9 publications, and New Zealand with 8. Countries like the Netherlands, Spain, Switzerland, and France also contribute to the literature, though to a lesser extent, with totals ranging from 6 to 7 publications. This distribution reflects a diverse global interest in the topic, with the United States being the predominant contributor, indicating strong research infrastructure and funding in this area.

Table 1 lists the top ten journals that have published research on Alzheimer's disease and gerontechnology. The Journal of Alzheimer's Disease ranks first with 6 total publications and an impact factor (IF) of 3.4, placing it in the second quartile (Q2) of journal rankings. Following closely is Research in Developmental Disabilities with 5 publications and an IF of 2.9, categorized in the first quartile (Q1). Other notable journals include Alzheimer's and Dementia and Frontiers in Aging Neuroscience, both in Q1 with impact factors of 4.0 and 4.1, respectively. The diversity of journals indicates a multidisciplinary approach to research in this field, with publications spanning various aspects of Alzheimer's disease, from clinical interventions to theoretical frameworks. This variety highlights the richness of the research landscape and the importance of disseminating findings across multiple platforms to reach broader audiences.

Most frequent author keywords and impactful research topics

Mapping author keywords with a minimum occurrence of three (n = 318) reveals critical insights into the research landscape of Alzheimer's disease and gerontechnology. The frequent keywords highlight interconnected themes that drive current studies and emerging trends, as shown in Fig. 3. The term "Alzheimer's Disease" stands out with 56 occurrences and a total link strength (TLS) of 46, reflecting its central role as a public health concern. The prominence of this keyword underscores the increasing academic focus on Alzheimer's disease as a major global health issue (Alzheimer's Disease International, 2019). Research on disease progression and its impact on daily life continues to be at the forefront, with studies emphasizing the role of assistive technologies in enhancing the quality of life for patients and their caregivers (Kearns et al., 2020).

"Dementia" appears 15 times with a TLS of 12, signifying the widespread exploration of cognitive impairments and their associated challenges for both patients and caregivers. This keyword's prominence highlights the broad scope of research that not only addresses

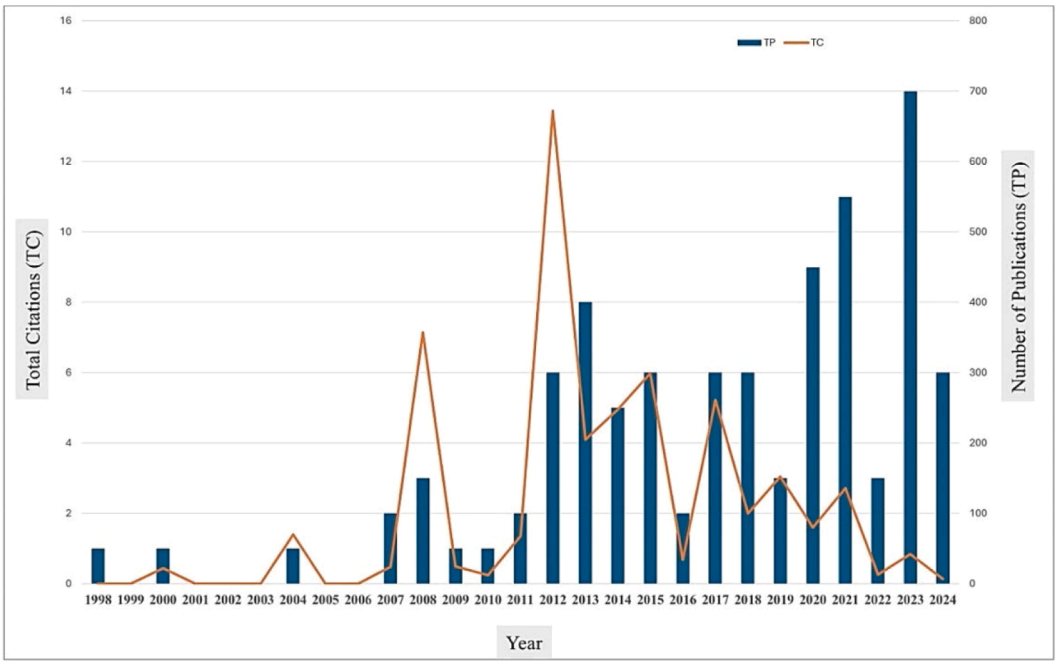


Fig. 1. The growth pattern of publications related publications related to Alzheimer's disease and gerontechnology.

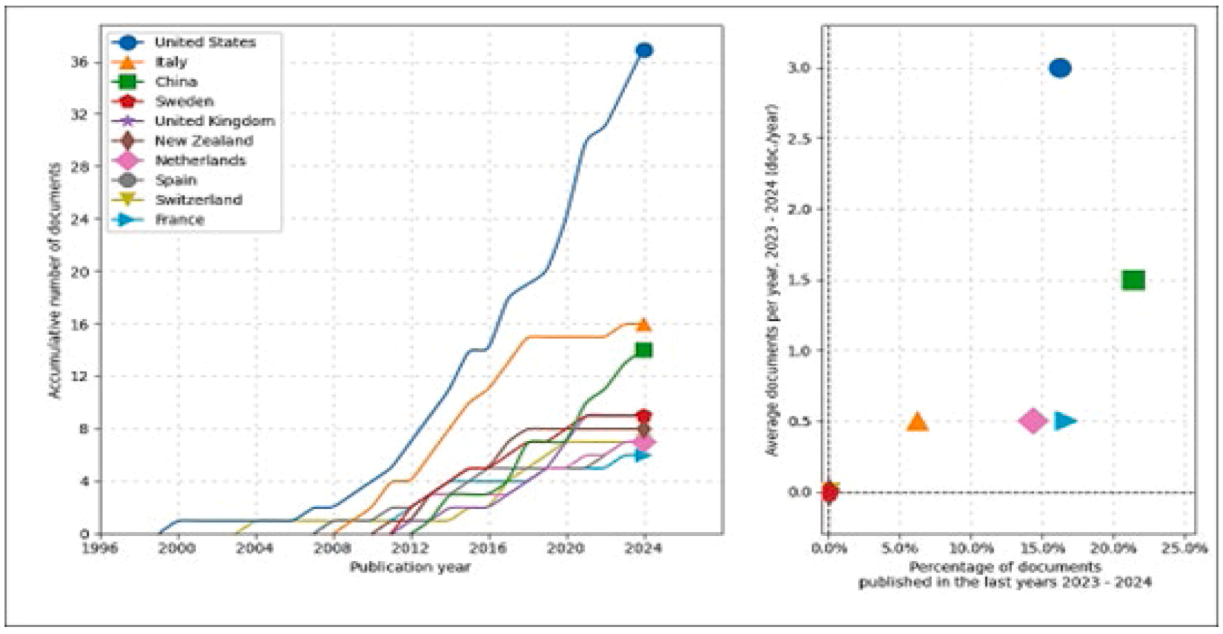


Fig. 2. The Top 10 countries active published related to Alzheimer's disease and gerontechnology.

Alzheimer's disease but also investigates other forms of dementia. Scholars like Livingston et al. (2020) have focused on the need for comprehensive approaches to dementia care that incorporate gerontechnology, with solutions ranging from cognitive training to telehealth services. This linkage underscores how technology can support independence in daily living, as emphasized by the recurring co-occurrence of keywords like "daily activities" and "technology".

The keyword "Technology" (10 occurrences, TLS of 16) highlights the growing integration of technological solutions in managing cognitive health, particularly in enhancing communication and monitoring among patients with cognitive impairments (Blok et al., 2020) This reflects a broader trend in gerontechnology research, where technology is increasingly seen as a tool not just for monitoring but for actively improving cognitive functioning and social engagement (Blok et al., 2020) The keyword "Mild Cognitive Impairment" (MCI), with 9 occurrences and a TLS of 14, signifies the critical focus on early-stage interventions. As Petersen et al. (2019) discuss, addressing MCI early with lifestyle modifications and technological aids can help delay progression to more severe cognitive decline(Hou et al., 2024). "Daily Activities" (6 occurrences, TLS of 12) highlights the practical focus of much Alzheimer's and gerontechnology research. The term emphasizes the growing body of work dedicated to improving everyday functioning through assistive technologies and supportive interventions (Meiland et al., 2017). The co-occurrence of terms like "caregiver support" and "telehealth" indicates the central role of technology in alleviating caregiver burden, an area of increasing importance as the demand for

Table 1
Top 10 journals.

JOURNAL	TP	Publisher	IF (JCR)	JIF QUARTILE
Journal of Alzheimers Disease	6	IOS Press	3.4	Q2
Research In Developmental Disabilities	5	PERGAMON-ELSEVIER SCIENCE LTD	2.9	Q1
Alzheimer's And Dementia	3	WILEY	4.0	Q1
Frontiers In Aging Neuroscience	3	Frontiers In Aging Neuroscience	4.1	Q2
Alzheimer's Research and Therapy	2	BMC	7.9	Q1
American Journal Of Alzheimer's Disease And Other Dementias	2	SAGE PUBLICATIONS INC	2.7	Q2
Clinical Interventions In Aging	2	DOVE MEDICAL PRESS LTD	3.5	Q2
Developmental Neurorehabilitation	2	TAYLOR & FRANCIS INC	1.1	Q4
Expert Opinion On Therapeutic Patents	2	TAYLOR & FRANCIS LTD	5.4	Q1
Scandinavian Journal Of Occupational Therapy	2	TAYLOR & FRANCIS LTD	1.9	Q2

informal care rises (Garnett et al., 2022)

Critique of keyword trends

While the frequent keywords provide valuable insights into the direction of Alzheimer's disease and gerontechnology research, there are notable gaps. Despite the integration of technology into Alzheimer's care, there remains limited attention on long-term effectiveness, particularly regarding how well these technologies are adapted across diverse populations. The keyword "Inclusivity", for instance, does not appear frequently, indicating that while gerontechnology is advancing rapidly, issues of accessibility and adoption among underrepresented groups are underexplored (Astell et al., 2019) This absence highlights a critical research gap, as interventions that fail to account for socioeconomic disparities, cultural preferences, and digital literacy may have limited efficacy and reach.

Moreover, although "Artificial Intelligence" (AI) and "machine learning" are increasingly popular in gerontechnology, these keywords did not rank among the top occurrences. This could suggest that while AI is recognized as a growing field, its practical application in Alzheimer's care remains in early stages. Researchers like Veneziani et al., (2024) have argued that more studies are needed to validate AI-driven tools for early diagnosis and monitoring, particularly in clinical settings. By analyzing keywords with high occurrences and TLS, several key research topics emerge that are shaping the current discourse in Alzheimer's disease and gerontechnology:

i. *The Role of Assistive Technology in Supporting Daily Activities for Alzheimer's Patients*
   This topic explores how various assistive technologies can improve the ability of individuals with Alzheimer's disease to perform daily activities independently. Frequent occurrences of keywords like "assistive technology" and "activities of daily living" reflect a growing body of research that focuses on improving patients' autonomy and quality of life. Recent studies have examined how smart home technologies, wearable devices, and sensor systems can enable better management of daily tasks, enhancing patients' dignity and reducing caregiver burden (Karikari et al., 2021; Lyall et al., 2023)
ii. *Cognitive Impairment and Its Impact on Quality of Life*
   Research in this area focuses on the relationship between cognitive impairment—particularly MCI and Alzheimer's disease—and overall quality of life. The investigation highlights the importance of early interventions to maintain well-being and social functioning. Studies by (Livingston et al., 2020) emphasize the need for a multi-pronged approach to managing MCI, incorporating both pharmacological and non-pharmacological interventions, including gerontechnology solutions like cognitive training and interactive applications.
iii. *Caregiver Burden and Support Strategies*
   As the prevalence of Alzheimer's disease increases, so too does the burden on informal caregivers. Research on this topic examines interventions aimed at alleviating this burden, often through

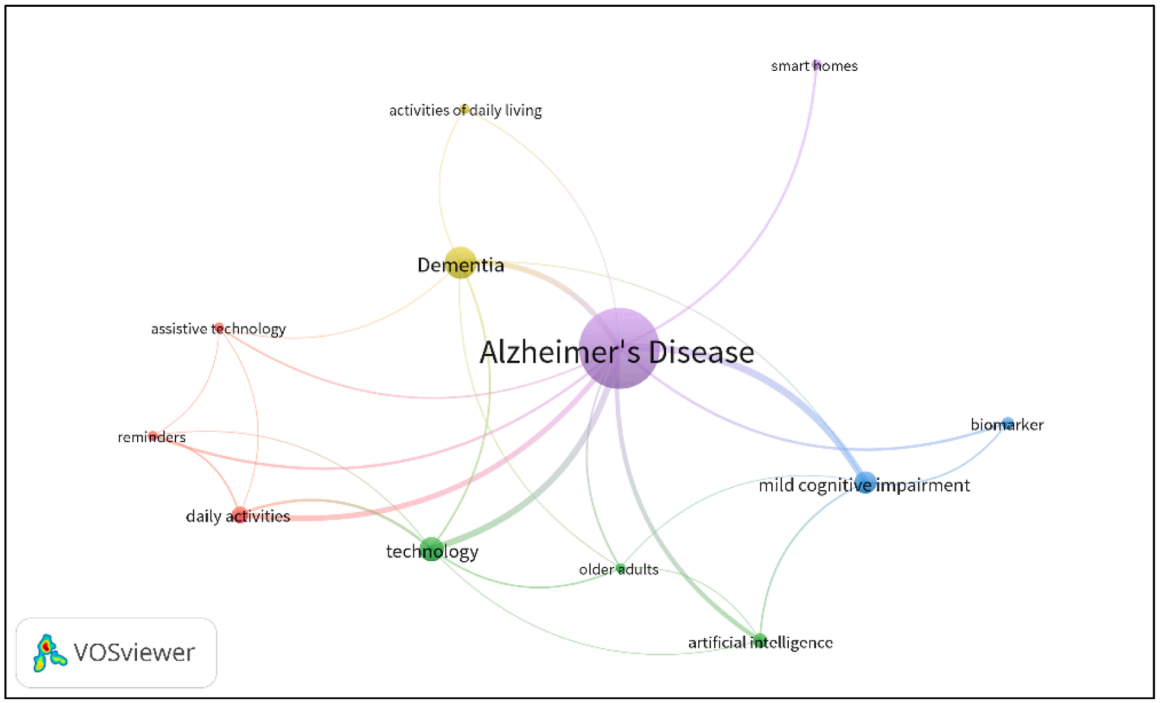


Fig. 3. Network visualization map of author keywords with a minimum occurrence of three in the retrieved articles on Alzheimer's disease and gerontechnology.

the use of remote monitoring systems and digital health platforms (Fjellström et al., 2014)The keyword co-occurrence suggests that caregiver support is a significant area of focus, with emerging technologies designed to improve communication between caregivers and healthcare professionals, providing timely interventions and reducing caregiver stress.

iv. *Artificial Intelligence in Early Diagnosis and Monitoring of Alzheimer's Disease*

The integration of AI into Alzheimer's care is a rapidly growing research area, with AI-driven tools showing potential for early diagnosis and real-time monitoring. Although AI did not appear as a frequent keyword, its emerging role is clear from studies like (Bakare et al., (2024) and Yao et al., (2023) which explore how machine learning algorithms can improve diagnostic accuracy by analyzing vast datasets from neuroimaging and genetic studies. However, as discussed (Mirkin & Albensi, 2023) there are still significant barriers to the practical implementation of these technologies, including data privacy concerns and the need for more robust clinical validation.

v. *The Impact of Aging on Cognitive Health and Disease Progression*

This topic explores the relationship between aging and cognitive health, focusing on how age-related changes contribute to the onset and progression of Alzheimer's disease. Demographic factors such as age, gender, and socioeconomic status can significantly influence disease progression and the effectiveness of interventions (Murman, 2015) Future research should focus on personalizing interventions to address the specific needs of diverse patient populations.

Emerging research topics

In addition to identifying the most impactful research topics in the fields of Alzheimer's disease and gerontechnology, it is critical to explore emerging trends that reflect the evolving nature of research in this domain. These trends often address critical gaps in knowledge and open up new avenues for innovative solutions to improve care for individuals affected by cognitive decline. By focusing on these emerging research topics, researchers can harness cutting-edge technologies and methodologies to enhance understanding, diagnosis, and treatment of Alzheimer's disease. The following three topics, identified from the dataset, highlight key areas that are gaining prominence in Alzheimer's research and gerontechnology:

1. Integration of Artificial Intelligence and Deep Learning in Cognitive Health Monitoring

Artificial intelligence (AI) and deep learning technologies are rapidly transforming how cognitive health is monitored, managed, and diagnosed. In the context of Alzheimer's disease, AI holds significant potential for developing predictive models that can assist in the early detection of cognitive decline. AI-driven tools can analyze large datasets from medical imaging, genomics, and electronic health records to detect subtle patterns indicative of Alzheimer's progression (Hu et al., 2023). These tools not only improve diagnostic accuracy but also enable personalized intervention strategies tailored to individual patients' needs, thereby enhancing patient outcomes.

Deep learning models, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have been particularly effective in analyzing neuroimaging data, identifying early biomarkers of Alzheimer's disease (Cabrera-León et al., 2024) Recent advancements in AI applications are also focused on real-time cognitive function tracking, allowing for continuous monitoring of disease progression and timely therapeutic interventions (Alowais et al., 2023). Despite these advances, challenges such as data privacy, the need for high-quality datasets, and the ethical implications of AI in healthcare remain critical areas of ongoing research (Mahmud et al., 2024).

2. Assistive Technology for Enhanced Daily Living Activities

The growing need for technologies that support individuals with Alzheimer's disease in performing daily living activities has brought attention to the role of assistive technologies. Smart homes, wearable devices, and ambient assisted living (AAL) systems are gaining traction as key solutions to help patients maintain independence and improve their quality of life (Sarita et al., 2024; Thakur et al., 2023) These technologies offer real-time monitoring of patient activity, medication reminders, and cognitive training exercises, which have proven effective in mitigating the cognitive and physical decline associated with Alzheimer's.

Research in this area emphasizes the importance of user-centered design, ensuring that assistive technologies are not only functional but also accessible and user-friendly for older adults with varying degrees of technological literacy (X. Chen et al., 2023) Additionally, recent studies have explored the integration of AI into AAL systems, allowing for adaptive learning algorithms that tailor interventions based on individual patient behavior(Kabudi et al., 2021) This combination of AI with assistive technologies presents a promising frontier in gerontechnology, although more studies are needed to assess long-term effectiveness, user acceptance, and inclusivity across different demographic groups.

3. Exploration of Biomarkers for Early Detection and Monitoring

Biomarkers, particularly blood and cerebrospinal fluid (CSF) indicators, are emerging as a critical focus area for early detection and monitoring of Alzheimer's disease. The identification of reliable biomarkers is essential for diagnosing Alzheimer's in its preclinical stages, long before significant cognitive impairment occurs (Kandiah et al., 2022). Current research is investigating a range of potential biomarkers, including beta-amyloid, tau proteins, and neurofilament light chain, which correlate with disease progression and can be tracked through non-invasive testing methods such as blood tests and advanced imaging (Georgakas et al., 2023)

The dataset highlights growing interest in the use of "blood biomarkers" and "cerebrospinal fluid", indicating a shift towards biomarker-driven approaches in Alzheimer's research. This trend has the potential to revolutionize diagnostic protocols, making them less invasive, more accessible, and more predictive of disease outcomes (Cai & Jia, 2024; Foley & Wilcock, 2024). However, there are challenges to be addressed, such as the variability in biomarker levels across different populations and the need for large-scale validation studies to confirm the clinical utility of these biomarkers in diverse patient groups. Fig. 4

Discussion

The integration of technology into the management of Alzheimer's disease has gained significant momentum, signaling a paradigm shift in how care is delivered. Recent research highlights the potential of biomarkers, particularly in the early detection of Alzheimer's, with blood-based and cerebrospinal fluid analyses offering promising avenues for identifying cognitive decline at its onset (Cai & Jia, 2024; Foley & Wilcock, 2024). These advancements allow for earlier intervention, which is crucial given the progressive nature of Alzheimer's. By facilitating personalized approaches to care, biomarker-driven diagnostics might provide a more nuanced understanding of disease progression, empowering clinicians to tailor interventions based on individual patient profiles.

Assistive technologies have equally transformative potential, enhancing the quality of life for individuals living with Alzheimer's disease by fostering autonomy and supporting daily living activities. Systematic reviews demonstrate the efficacy of technologies such as smart homes, wearables, and cognitive training applications in improving patient independence (Klimova et al., 2018; Schneider et al., 2024). These innovations reduce caregiver burden and enhance patient well-being, particularly by offering real-time monitoring and customized care solutions. As the aging population continues to grow, the development of inclusive, user-friendly technologies is essential to meet the needs of diverse demographics, from technologically literate patients to those who may struggle with complex systems.

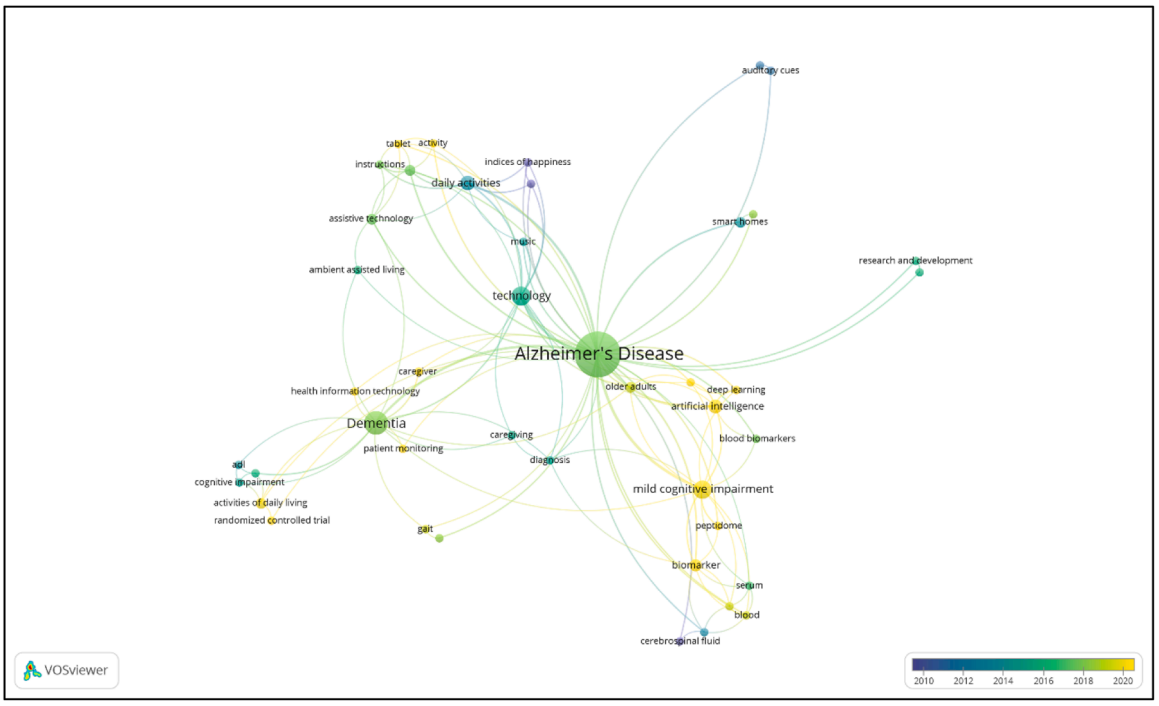


Fig. 4. Overlay visualization map of author keywords with a minimum occurrence of three in the retrieved articles on Alzheimer's disease and gerontechnology.

The burden on caregivers of individuals with Alzheimer's disease remains a critical issue. Caregivers often face emotional and physical tolls compounded by inadequate support systems (Vu et al., 2022). Technology-based interventions, such as remote monitoring systems and telehealth platforms, provide much-needed relief by enabling caregivers to track patient health remotely and access real-time assistance (Angelopoulou et al., 2022). These systems not only empower caregivers but also enhance communication between families and healthcare professionals, ensuring more coordinated and comprehensive care. Despite these benefits, variability in technology adoption among caregivers, often due to differences in technological literacy and resource availability, remains a significant challenge that must be addressed (Lindeman et al., 2020).

Artificial intelligence (AI) and machine learning (ML) have emerged as powerful tools in the diagnosis and management of Alzheimer's disease. The ability of AI to process large datasets from neuroimaging, genetics, and electronic health records enables the identification of patterns that may signal early cognitive decline, which traditional diagnostic methods may overlook (Fabrizio et al., 2021). However, as AI systems become more integrated into Alzheimer's care, ethical considerations, particularly regarding data privacy, algorithmic bias, and transparency, must be carefully managed. Ensuring that AI systems are reliable, interpretable, and aligned with ethical healthcare practices is critical to their widespread acceptance.

In addition to AI, advanced neuroimaging and deep learning techniques hold great promise for future research directions. Neuroimaging analyses powered by AI, as demonstrated by Zhou et al. (2018) and Xu et al. (2014), have the potential to yield insights into disease progression, allowing for more accurate modeling of Alzheimer's stages. These models can inform the development of personalized treatment strategies that evolve alongside the patient's condition, making care more dynamic and responsive. Nonetheless, the field must address challenges related to the accessibility of these advanced technologies, particularly in low-resource settings.

Virtual reality (VR) and augmented reality (AR) technologies are gaining traction in Alzheimer's care, offering innovative solutions for cognitive training and social interaction. Research by Sokołowska (2023) shows that VR environments can provide immersive experiences that stimulate cognitive function, engagement, and memory recall, presenting an innovative complement to traditional therapies. However, large-scale clinical validation is needed to ensure the long-term efficacy of these interventions.

The increasing recognition of interdisciplinary collaboration in Alzheimer's research is another key trend. Combining expertise from neuroscience, engineering, psychology, and data science has led to the co-creation of technologies that are not only effective but also user-centered (Tan et al., 2021). This collaborative approach ensures that technological solutions are designed with the input of patients and caregivers, making the technologies more relevant, usable, and impactful.

Inclusivity remains a persistent challenge in integrating gerontechnology into Alzheimer's care, particularly among underserved groups. Barriers such as socioeconomic disparities, limited access to digital infrastructure, and cultural differences impede adoption. For example, rural communities often lack access to stable internet, limiting the effectiveness of telehealth solutions. Similarly, older adults in lower socioeconomic strata may struggle with affordability and technological literacy. Case studies highlight these challenges: a pilot program in rural India using low-cost wearable devices demonstrated improved cognitive monitoring but faced resistance due to cultural stigmas surrounding mental health (Singh et al., 2023). Another example in the U.S. showed that mobile apps designed for Hispanic populations gained traction only after being localized linguistically and culturally (Gonzalez et al., 2021). Addressing these disparities requires user-centered designs that account for the needs and preferences of diverse demographic groups (Hand & Ihara, 2024).

Approaches to Alzheimer's and gerontechnology research vary significantly across regions, shaped by policy frameworks, funding mechanisms, and cultural attitudes. For instance, the United States leads in public-private partnerships, with initiatives such as the NIH's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, fostering innovation in AI-based diagnostics (Nichols et al., 2022). In contrast, Italy's policy emphasis lies in integrating technology into community-based care, evidenced by regional funding schemes promoting assistive devices (Meiland et al., 2017). Meanwhile, China's rapid advances in gerontechnology stem from national priorities

outlined in the "Healthy China 2030″ blueprint, focusing on AI-driven tools for early intervention (Yubo et al., 2023). However, barriers persist: U.S. initiatives face challenges related to unequal resource distribution, while Italy struggles with scalability in rural regions, and China's progress is hindered by privacy concerns related to AI (Hou et al., 2024).

The long-term impact of gerontechnology in clinical settings is promising yet underexplored. Predictive models, such as those derived from longitudinal neuroimaging data, suggest that early interventions with assistive technologies can delay disease progression by up to five years (Fabrizio et al., 2021). A 10-year study tracking smart home technology adoption revealed sustained improvements in patient autonomy and reductions in caregiver burden (Lyall et al., 2023). Furthermore, predictive algorithms integrated into wearable devices provide real-time monitoring, enabling timely clinical interventions (Hou et al., 2024). Ensuring sustained impact requires addressing issues such as technology maintenance, user adherence, and clinician training.

The evolution of technology in Alzheimer's care reflects a paradigm shift from passive monitoring to active intervention. Early innovations, such as memory aids and basic assistive devices, have given way to sophisticated systems like AI-driven diagnostic tools and immersive virtual reality therapies (Sokołowska, 2023). Trends in the last decade highlight increasing integration of wearable sensors for continuous health monitoring and telehealth platforms for remote consultations (Schneider et al., 2024). Emerging technologies like AR are now being explored to enhance cognitive training by creating immersive, interactive environments (Angelopoulou et al., 2022). This trajectory underscores a movement toward personalized, patient-centered care, with future advancements likely focusing on enhancing accessibility and interoperability among diverse technologies.

While the study utilized Web of Science and Scopus, we recognize that this approach may have excluded critical interdisciplinary studies available in PubMed, IEEE Xplore, or ACM Digital Library. This limitation could impact the comprehensiveness of the identified trends, particularly in technical and medical research domains. Future analyses should integrate these additional databases to enhance coverage and provide a more holistic view of gerontechnology research.

A key limitation of the current study is the lack of a detailed assessment of the quality and rigor of included studies. While peer-reviewed articles were prioritized, publication bias and variability in methodological robustness across papers were not explicitly evaluated. Incorporating a meta-analysis of study designs, sample sizes, and methodologies in future research could strengthen the conclusions and help differentiate genuinely promising trends from potentially under-validated approaches.

Although the dataset includes publications up to August 31, 2024, the analysis of trends primarily focuses on data up to 2021. This discrepancy arose from delays in processing the most recent records. We are updating the analysis to include trends from 2022 to 2024, which could reveal critical emerging directions. Furthermore, global events such as the COVID-19 pandemic have profoundly influenced research patterns and technology adoption. For instance, the pandemic catalyzed rapid advancements in telehealth and remote monitoring solutions, reshaping the gerontechnology landscape.

The adoption of gerontechnology faces significant real-world challenges, including technology acceptance among elderly populations, cost barriers, caregiver training requirements, and infrastructure needs. While these issues were mentioned, they warrant deeper exploration. For example, case studies could illustrate how pilot programs have addressed these barriers in resource-limited settings. This analysis is essential to bridge the gap between research innovation and practical application.

While bibliometric visualizations provided useful insights into co-authorship and keyword co-occurrences, the full potential of network analysis was not fully exploited. Future studies could incorporate advanced techniques to examine research collaboration dynamics, knowledge transfer between sub-fields, and the evolution of themes over time. Such analyses could uncover opportunities for enhanced interdisciplinary collaboration and identify unexplored research directions.

Conclusion

This study highlights the growing integration of technology into Alzheimer's care, emphasizing its transformative potential across biomarkers, assistive technologies, and AI-driven solutions. However, limitations in database selection, evaluation of study rigor, and inclusion of recent trends suggest areas for improvement. Incorporating additional databases, critically assessing methodological robustness, and analyzing post-2021 publications could enhance future research. Furthermore, addressing implementation challenges such as cost, accessibility, and caregiver training is essential for the real-world adoption of gerontechnology. Advanced network analyses could provide deeper insights into interdisciplinary collaborations and emerging trends, offering a roadmap for future research and innovation in this vital field.

Data Sharing Statement

This statement outlines the policies regarding the availability of data used in the research, specifying whether data can be shared publicly and under what conditions.

CRediT authorship contribution statement

Azliyana Azizan: Writing – review & editing, Writing – original draft, Visualization, Software, Formal analysis, Conceptualization. **Susi Endrini:** Writing – review & editing, Resources. **Khairul Hafezad Abdullah:** Writing – review & editing, Validation, Project administration.

Declaration Of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors have contributed significantly to the research and preparation of this manuscript and approve its submission for publication.

Data availability

Data will be made available on request.

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