REVIEW PAPER

Artificial Intelligence and Digital Biomarkers: An Advanced Perspective in Diagnosing Alzheimer's Disease

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ABSTRACT

Alzheimer's disease is a neurological disorder that progressively degrades the brain cells, leading to a gradual decline in cognitive and behavioural functions. In the year 2022, Alzheimer's disease was the seventh largest cause of death in the United States, as reported by the Centers for Disease Control and Prevention (CDC). AI-based tools help the psychiatrists and other health care professionals in diagnosing the Alzheimer's disease. AI keeps track of the patient prognosis and their response to the treatment. AI could change the way of health care professionals learn by showing them the diagnostic patterns and insights that other methods don't. Patients will become more likely to adhere to their treatment plans because AI comforts the patients to get involved by using the data driven visuals and personalized explanations. This review focuses on the role of artificial intelligence in diagnosing Alzheimer's Disease and the initiatives & technological innovations along with the new advancements in AI-augmented analysis of individual digital biomarkers. This review also highlights the importance of AI Predictive Models for Alzheimer's disease and the concept of Federated Learning and Privacy-Preserving AI. The existing approaches of detecting Alzheimer's disease might be transformed if AI models are developed with proper ethics, clinical validation and high-quality data as priorities. The enhanced efficiency of healthcare delivery is a direct consequence of these instruments' capacity to assist the health care professionals in performing the early diagnoses and delivering superior treatment and enhanced patient care.

Keywords: *Alzheimer's disease, Artificial Intelligence, Digital Biomarkers, Neurodegeneration.*

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INTRODUCTION

Alzheimer's disease (AD) is a neurological disorder that progressively degrades the brain cells, leading to a gradual decline in cognitive and behavioural functions. The capacities to recall, comprehend, articulate, concentrate, reason and make decisions are integral to these processes. In the year 2022, Alzheimer's disease was the seventh largest cause of death in the United States, as reported by the Centers for Disease Control and Prevention (CDC). COVID-19 was the fourth leading cause among the top five. Before the COVID-19 pandemic, Alzheimer's disease ranked second to stroke in overall fatality rates[1,2]. Alzheimer's disease is referred to as late-onset Alzheimer's disease (LOAD) when it usually presents after the age of 65 years. Nonetheless, slightly more than 5% of Alzheimer's disease patients have early-onset Alzheimer's disease (EOAD), which manifests prior to the age of 65 years. In 1990, 20.3 million individuals worldwide experienced dementia[3]. Following a substantial increase of 116%, the figure attained 43.8 million by 2016. Projections suggest that the present population of individuals afflicted with dementia will increase fourfold to 150 million by the year 2050[4].

Neurodegeneration, marked by the degradation of neuronal cells, is a hallmark of Alzheimer's disease. The entorhinal cortex, which is a part of the hippocampus, is where the neurodegenerative diseases often start. Genetic factors are known to play a role in both early-onset and late-onset Alzheimer's disease and Trisomy 21 is a risk factor for early-onset dementia[5]. A history of brain injury, depression, cardiovascular and cerebrovascular disorders, having an older parent at birth, smoking, high homocysteine levels, a family history of dementia and the presence of the APOE e4 allele are the factors that could lead to Alzheimer's disease (AD) for an individual[6-8]. The difficulties in formulating consensus criteria, the limited availability of biomarkers and neuropsychiatric evaluations and the frequent instances of differential diagnoses hinder the classification of Alzheimer's disease as a separate entity[9]. In the last ten years, there have been major steps forward in the creation of biomarkers that make it easier to find Alzheimer's disease (AD) early and accurately. Neuro imaging markers obtained through amyloid and tau PET

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scans, cerebrospinal fluid and plasma markers are considered. Currently, there is no definitive approach to impede the progression of Alzheimer's disease; nevertheless, some drugs can alleviate specific symptoms.

ROLE OF ARTIFICIAL INTELLIGENCE IN DIAGNOSING ALZHEIMER'S DISEASE

AI-based tools help the psychiatrists and other health care professionals in diagnosing the Alzheimer's disease. AI keeps track of the patient prognosis and their response to the treatment. AI could change the way of health care professionals learn by showing them the diagnostic patterns and insights that other methods don't. Patients will become more likely to adhere to their treatment plans because AI comforts the patients to get involved by using the data driven visuals and personalized explanations[10].

The intersection of digital technology and artificial intelligence (AI) is enabling a new means of diagnosing Alzheimer's disease to detect slight changes in behavior, cognition and physiology in daily life, often without the need for invasive procedures. In AI, specifically machine learning (ML) and deep learning (DL) algorithms are central in analyzing these frequently complex and large data streams to detect the trends of AD that can forecast the disease progression and tailor interventions.
Passive asssesements are rapidly emerging as a pivotal advancement in this sector. Digital bio-markers are quantitative signals that are derived from data recorded by the continuous digital monitors like smart-phones, wearables and sensors[11]. Instances of passive data encompass sleep metrics, activity trends and device usage statistics.
Ecological momentary assessments (EMAs), smartphone-based cognitive evaluations and voice samples for analysis are often augmented for active assessments. To offer a more holistic perspective on an individual's health, AI algorithms amalgamate many digital indications into composite measures. This excels at detecting the subtle, early changes in Alzheimer's disease that usually manifest prior to observable clinical signs.

INITIATIVES AND TECHNOLOGICAL INNOVATIONS

SpeechDx Dataset for Speech-Based Biomarkers: The Alzheimer's Drug Discovery Foundation's Diagnostics Accelerator (DxA) published a press release announcing a partnership with Siemens Healthineers to license the DxA's SpeechDx Dataset. This dataset is described as a gold-standard repository of Alzheimer's speech biomarkers. The agreement is intended to leverage Siemens Healthineers' strength in developing a clinically viable speech-based biomarker for AD.
AI-Enabled Digital Cognitive Assessment (MoCA Solo): DxA invested to further develop MoCA Solo, an artificial intelligence-enabled digital cognitive assessment platform with the aim to improve the ability of earlier AD detection that will help the primary care health professionals, who are usually the first point of contact for the patients with cognitive impairment.
Ocular Biomarkers as a Non-Invasive Tool: A recent DxA paper emphasized the use of ocular tests as a non-invasive detection tool for at-risk populations of AD. The results, released in Alzheimer's & Dementia, indicate that while blood biomarkers will become a routine clinical diagnosis tool where as the ocular biomarkers processed with AI can serve as an alternative[12,13].
Smart Phone-Derived Digital Biomarkers and AI for Remote Monitoring: Studies on smart phone-based digital biomarkers are ongoing. Integrated frameworks are being formulated to capture passive (e.g: patterns of activity from accelerometers/gyroscopes, device usage history, sleep measurements from actigraphy) and active digital biomarkers (e.g: ecological momentary assessment of symptoms/mood, brief cognitive tests via app and voice samples for machine learning analysis)[14]. To extract the important signatures from this data, AI processing utilises several algorithms of deep learning and machine learning. It can identify patterns of lethargy or cognitive deterioration in neurological illnesses that are clearly applicable to Alzheimer's disease. Digital indicators like typing accuracy, sleep efficiency and gait variability can yield composite metrics that offer a clear perspective of an individual's health by these AI systems.

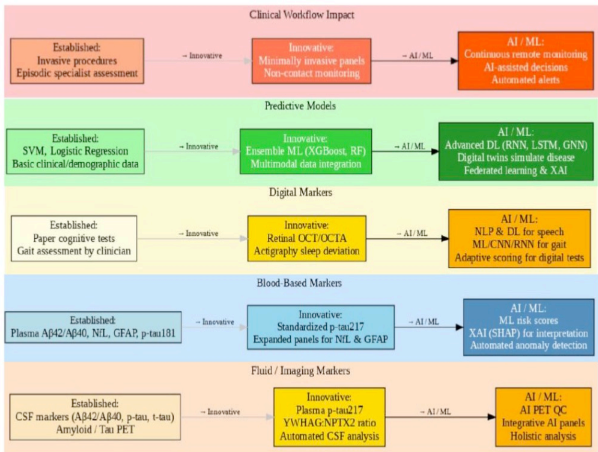

Figure 1: Comparison of traditional and digital bio-markers in Alzheimer's diagnosis

AI-AUGMENTED ANALYSIS OF INDIVIDUAL DIGITAL BIOMARKERS: NEW ADVANCES

Speech Analysis: Speech analysis may reveal alterations in connected speech, evidenced by variations in lexical-semantic content (including word selection and diversity), acoustic-phonetic characteristics (such as pitch, tempo & pauses) and grammatical complexity, potentially preceding the overt manifestations of Alzheimer's disease. National Institutes of Health (NIH) – has an ongoing funded study that deals with machine learning and natural language processing (NLP) methods applied to audio recordings of the subjects. The research seeks to define digital biomarkers of speech associated with AD biomarker status and to forecast cognitive trajectory over time[15]. A recent study by this research group proved that AI in fact could identify the early AD signs in speech characteristics. Further in support of this strategy, Amini S et al employed an AI model to examine the speech transcripts of cognitive tests given to participants in the Framingham Heart Study. This model examined the language structure from automated transcripts (without analyzing acoustic properties), successfully predicted the subjects with Mild Cognitive Impairment (MCI) would develop AD in six years with a rate of more than 78% prevalence. Universal Sentence Encoder was utilized for generating the vector embeddings of speech segments and a logistic regression model was used for prediction in this study[16].

Gait Analysis: Abnormal gait, such as reduced stride length, greater variability and lower cadence, has been recognized as potential early indicators of cognitive deterioration and Alzheimer's Disease (AD). Wearable sensors, i.e., accelerometers in smartwatches or specialized devices and motion capture systems are used to capture fine gait data. Artificial Intelligence (AI) techniques such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) helps in identification of spatial pattern and for the assessment temporal sequence respectively in gait that can label the participants as healthy or at risk for AD[17].

Ocular Biomarkers: The eye and the retina in particular, provide a "window to the brain" because of shared embryological origin and vascular supply. AI is being used to study a range of ophthalmic imaging modalities and the AI algorithms can scrutinize retinal photographs (e.g: fundus photography) and Optical Coherence Tomography Angiography (OCT-A) scans for early subtle changes (such as macular vessel density or retinal nerve fiber layer thickness changes) that have been associated with AD pathology and cognition. AI-augmented ophthalmic imaging is being investigated as a non-invasive user-friendly screening tool for the identification of individuals at increased risk for AD[18].

While individual digital biomarkers are very promising, the true potential of AI in AD diagnosis probably lies in its ability to synthesize and interpret complex, heterogeneous streams of data. The capacity of AI to calculate composite scores relies on the concept of multimodal digital phenotyping, encompassing data from ocular scans, sleep patterns, activity levels, gadget interactions, movement and vocal analysis. Artificial intelligence may compute composite scores by assessing the data from ocular scans and the intercommunication of devices. Composite scores may offer a more thorough, precise and individualized assessment of a person's neurological and cognitive health compared to the individual scores. This method addresses the complexity and variety of AD due to its extensive consequences.

Further research into suitable data fusion methodologies is necessary to evaluate these AI-generated composite scores against established clinical and pathological criteria. Conventional validation procedures and comprehensive regulatory frameworks are behind the fast proliferation of AI-driven digital biomarkers. Consequently, there is an urgent necessity to formulate succinct guidelines for the ethical and effective therapeutic application of these novel technologies and to perform clinical validation against established gold standards, such as cerebrospinal fluid and positron emission tomography biomarkers[19].

PREDICTIVE MODELS (AI) FOR ALZHEIMER'S DISEASE

Advancements in AI for Alzheimer's disease prediction have evolved from fundamental models utilizing limited datasets to intricate systems capable of processing extensive multimodal data, enabling more customized evaluations of risk and disease progression along with earlier symptom identification. With the use of novel biomarkers, enhanced data accessibility and advancements in AI methodologies may be segmented into several phases in the aspect of their progress.

Predictive Artificial Intelligence for Alzheimer's Disease (Early Predictive Models and Risk Factor Identification): Initially, artificial intelligence (AI) was utilised to predict Alzheimer's disease (AD) mostly by employing traditional machine learning algorithms on accessible demographic data, clinical records and risk factors. Initial models often used fundamental techniques such as logistic regression and support vector machines (SVMs), which were applicable to relatively uncomplicated organized datasets. For example, several preliminary researches used multivariate logistic regression to examine variables such as gender, age, socioeconomic status, overall health, lifestyle choices (including smoking) and general genetic risk factors. These models were frequently short on the sophistication of segmented features or the capability to identify complex, non-linear interactions that limited their utility and predictive power in the real-world applications[20].

Role of AI in Alzheimer's Disease prediction (Next-Generation Medicine (NGM) with Clinical, Psychosocial and Genetic Data): The second phase of AI-based predictions for Alzheimer's disease is the use of sophisticated machine learning techniques such as Random Forest technique, Classification technique and Extreme Gradient Boosting (XGBoost) technique and Deep Learning techniques. These bigger datasets allowed researchers to predict AD onset and progression with the use of a much larger number of predictors. Models are incorporated with complex personal features, large amounts of clinical information, psychosocial variables and more specific genetic metrics (APOE genotype and detailed family history of cognitive impairment). A recent study revealed an XGBoost model of AD risk prediction and this model was trained on NACC (National Alzheimer's Coordinating Center) data using 11 significant variables including education level, depression, insomnia, age, BMI, number of medications, gender, stenting history, systolic blood pressure, neurosis and REM sleep abnormalities[21]. This work employed model interpretability techniques such as Shapley Additive Explanations (SHAP) to elucidate the influence of various factors on predictions. Research indicated that higher education conferred a protective benefit, but advanced age and polypharmacy correlated with increased risks. During this period, there was an initiative to enhance prediction accuracy and reveal more intricate patterns and interactions among an expanded array of predictive factors. This was facilitated by the emergence of extensive research databases, like the NACC-UDS (National Alzheimer's Coordinating Center Uniform Data Set) and ADNI (Alzheimer's Disease Neuroimaging Initiative) databases.

Prognosis in Alzheimer's Disease Utilising AI and Digital Biomarkers: The most advanced AI for predicting Alzheimer's disease integrates cutting-edge digital biomarkers with refined AI techniques to deliver earlier and more personalised assessments of disease risk and development pathways. This approach utilises AI's capacity to amalgamate data from several sources by integrating electronic biomarkers and digital biomarker streams with traditional clinical, genetic and imaging data[22].

ADVANCED ARTIFICIAL INTELLIGENCE METHODS FOR PERSONAL FORECASTING

State-Space Models: Longitudinal data including findings from several cognitive evaluations or measurements of identical biomarkers collected at various time intervals can be analysed using state-space models (SSMs).

Deep Learning Temporal Models: Multivariate time series comprising clinical, cognitive and imaging data collected at varying intervals are optimal for training Deep Learning Temporal Models (e.g., RNNs and LSTMs) to uncover the complex temporal connections.

Graph Neural Networks (GNNs): They have a unique capability to represent relational patterns such as functional or structural brain connectivity networks of neuroimaging data or patient similarity graphs of multimodal features.

Deep Generative Models and AI-Driven Digital Twins: Conditional Restricted Boltzmann Machines (CRBMs) and other generative models provide innovative methodologies for creating "digital twins" of patients. The objectives of these models are to predict and simulate patient-specific disease trajectories across numerous hypothetical scenarios. This facilitates *in-silico* experimentation by accounting for variables such as the potential effects of medicines. The objective is to attain data integration across various modalities, encompassing neuroimaging techniques (sMRI, PET, DTI, rs-fMRI), fluid biomarkers (CSF Aβ42, t-tau, p-tau), genetic information (APOE genotype, SNPs), clinical & cognitive assessments, demographic data and newly developed digital biomarkers to formulate comprehensive predictive models[23-25].

Explainable AI (XAI) for Prediction Models: Proper utilization of XAI methods such as SHAP (SHapley Additive exPlanations), LIME (Local Interpretable Model-agnostic Explanations) and Grad-CAM (Gradient-weighted Class Activation Mapping) must be done as these models get progressively intricate that elucidates the predictive potential of both digital and non-digital elements. The mechanisms of these models enhance the clinical confidence that can only aspire and reveals novel predictive signals. XAI can identify which areas of the brain or other digital characteristics are most significant for forecasting the beginning or progression of Alzheimer's disease (AD). This interpretability is essential to "open the black box" and guarantees model fairness by showcasing their performance across a diverse group of individuals[26].

Table 1: Predictive Models in Alzheimer's Disease Diagnosis

S. No	Study/Model	Dataset	Method Adopted	Year
1	**Random Forest[27]**	ADNI	Random Forest	2021
2	**RNN, LSTM[28]**	ADNI	Sequential DL (LSTM-RNN)	2022
3	**3D-CNN[29]**	ADNI, NACC, KAGGLE	3D-CNN with DAG Framework	2025
4	**VGG16/DenseNet169/ Ensemble[30]**	OASIS-2	DL Ensemble with Transfer Learning	2024
5	**AlexNet[31]**	Kaggle	CNN, Transfer Learning	2022
6	**ResNet-50[32]**	ADNI	Deep Learning with Transfer Learning	2024
7	**Ensemble ML** (DT, RF, SVM, XGBoost, Voting)[33]	OASIS	Ensemble ML	2022
8	**SVM, RF, BERT[34]**	ADReSS	ML/NLP	2022
9	**DNN[35]**	ADNI	Deep Neural Network	2021

			Binary Classifier	

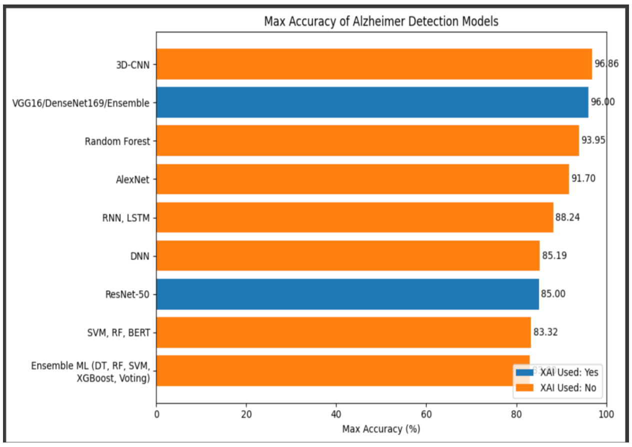

Figure 2: Exploratory Data Analysis of Predictive Models in Alzheimer's Disease Diagnosis

FEDERATED LEARNING AND PRIVACY-PRESERVING AI

With the requirement for massive and varied sets of data to generate strong artificial intelligence models and the rigid privacy regulations that cover health information, federated learning (FL) and other privacy-preserving artificial intelligence techniques are becoming progressively essential. The Secure Federated Learning architecture in preparation under NIH Project is an example for the project that will allow computation on distributed global biobanks (over 100,000 neuroimaging scans and genomic data from the US, Europe, India and Japan) without sharing the data directly. It uses federated deep learning, data harmonization techniques to derive site-invariant predictors and secure homomorphic encryption to protect patient privacy.

The primary long-term objective of the models is to generate precise, individualised forecasts regarding cognitive and pathological trajectories, surpassing mere risk classification or assessments at the population level. This can be achieved by addressing prevalent data challenges encountered in extensive biological studies, including high dimensionality, data sparsity, irregular sampling, substantial missing data and data imbalance. AI-driven solutions, like transfer learning, sophisticated data imputation methods and synthetic data creation utilising Variational Autoencoders (VAEs) or Generative Adversarial Networks (GANs) are employed to address these challenges. An increasing array of digital biomarkers is utilised by these systems, which rely on multimodal information[36-47].

CONCLUSION

The existing approach of detecting Alzheimer's disease might be transformed if AI models are developed with proper ethics, clinical validation and high-quality data as priorities. The enhanced efficiency of healthcare delivery is a direct consequence of these instruments' capacity to assist the health care professionals in performing the early diagnoses and delivering superior treatment and enhanced patient care..

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REFERENCE

1. Ahmad FB, Cisewski JA, Xu J, Anderson RN. Provisional Mortality Data - United States, 2022. MMWR Morb Mortal Wkly Rep. 2023 May 05;72(18): 488-492.
2. Mendez MF. Early-Onset Alzheimer Disease. Neurol Clin. 2017 May; 35(2): 263-281.
3. Li X, Feng X, Sun X, Hou N, Han F, Liu Y. Global, regional, and national burden of Alzheimer's disease andother dementias, 1990-2019. Front Aging Neurosci. 2022; 14: 937486.
4. Santos CY, Snyder PJ, Wu WC, Zhang M, Echeverria A, Alber J. Pathophysiologic relationship betweenAlzheimer's disease, cerebrovascular disease, and cardiovascular risk: A review and synthesis. Alzheimers Dement (Amst). 2017; 7: 69-87.
5. Nicolas G, Acuña-Hidalgo R, Keogh MJ, Quenez O, Steehouwer M, Lelieveld S, Rousseau S, Richard AC, Oud MS,Marguet F, Laquerrière A, Morris CM, Attems J, Smith C, Ansorge O, Al Sarraj S, Frebourg T, Campion D,Hannequin D, Wallon D, Gilissen C, Chinnery PF, Veltman JA, Hoischen A. Somatic variants in autosomal dominantgenes are a rare cause of sporadic Alzheimer's disease. Alzheimers Dement. 2018 Dec; 14(12): 1632-1639.
6. Liljegren M, Landqvist Waldö M, Rydbeck R, Englund E. Police Interactions Among NeuropathologicallyConfirmed Dementia Patients: Prevalence and Cause. Alzheimer Dis Assoc Disord. 2018 Oct-Dec; 32(4): 346-350.
7. Tong BC, Wu AJ, Li M, Cheung KH. Calcium signaling in Alzheimer's disease & therapies. Biochim BiophysActa Mol Cell Res. 2018 Nov; 1865(11 Pt B): 1745-1760.
8. Tahami Monfared AA, Byrnes MJ, White LA, Zhang Q. Alzheimer's Disease: Epidemiology and Clinical Progression. Neurol Ther. 2022 Jun; 11(2): 553-569.
9. Zetterberg H, Bendlin BB. Biomarkers for Alzheimer's disease-preparing for a new era of disease-modifying therapies. Mol Psychiatry. 2021 Jan; 26(1): 296-308.
10. Zhang W, Li Y, Ren W, Liu B. Artificial intelligence technology in Alzheimer's disease research. Intractable Rare Dis Res. 2023 Nov; 12(4): 208-212.
11. Wang Y, Li Y, Wang S, Zhang Y, Chen K, Zhang J, et al. Development and validation of machine learning models with blood digital biomarkers for Alzheimer's disease and mild cognitive impairment. Lancet Digit

Health. 2025 Mar 5; 7(3):e210–e221.
12. Gure TR, Liss J, Abraham J, et al. Cognitive digital biomarkers from automated transcription of speech for early Alzheimer’s detection. Sensors (Basel). 2024; 24(5): 1572.
13. Livingston G et al. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. The Lancet, 2020; 396(10248): 413-446.
14. Oh HS, Urey DY, Karlsson L, Zhu Z, Shen Y, Farinas A et al. A cerebrospinal fluid synaptic protein biomarker for prediction of cognitive resilience versus decline in Alzheimer's disease. Nat Med. 2025 May; 31(5):1592-1603.
15. Guo T, Shaw LM, Li Y, et al. Advances in blood biomarkers for Alzheimer’s disease: ultra-sensitive detection technologies and clinical applications. Front Aging Neurosci. 2024 Jul 30; 16: 11297492.
16. Amini S, Hao B, Yang J, Karjadi C, Kolachalama VB, Au R, Paschalidis IC. Prediction of Alzheimer's disease progression within 6 years using speech: A novel approach leveraging language models. Alzheimers Dement. 2024 Aug; 20(8):5262-5270.
17. Nunez N, Sanz A, Garcia A, et al. Multidimensional digital biomarker phenotypes for mild cognitive impairment and early Alzheimer’s disease. Front Digit Health. 2024; 6: 1265846.
18. Rabin LA, Smart CM, Amariglio, R.E. Subjective cognitive decline in preclinical Alzheimer’s disease. Annual Review of Clinical Psychology, 2017; 13: 369-396.
19. Sperling RA et al. Toward defining the preclinical stages of Alzheimer’s disease: Recommendations from the National Institute on Aging - Alzheimer’s Association workgroups. Alzheimer’s & Dementia, 2011; 7(3), 280-292.
20. Bzdok D, Meyer-Lindenberg A. Machine learning for precision psychiatry: Opportunities and challenges. Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 2018; 3(3): 223-230.
21. Ismail Z, Rajji TK, Shulman KI. Brief cognitive screening instruments: An update. Int J Geriatr Psychiatry. 2010 Feb; 25(2): 111-120.
22. Piau A et al. A smartphone application for self-management of health and chronic conditions: A systematic review. Health Informatics Journal, 2019; 25(3), 1060-1078.
23. Varatharajah, Y., et al. (2019). Predicting short-term MCI-to-AD progression using multi-modal deep learning. Scientific Reports, 2019; 9: 2235.
24. Kourtis LC, Regele OB, Wright JM, Jones GB. Digital biomarkers for Alzheimer’s disease: The mobile/wearable devices opportunity. NPJ Digital Medicine, 2019; 2: 9.
25. Insel TR. Digital phenotyping: Technology for a new science of behavior. JAMA, 2017; 318(13): 1215-1216.
26. Eyigoz E, Mathur S, Santamaria M, Cecchi G, Naylor M. Linguistic markers predict onset of Alzheimer’s disease. E Clinical Medicine. 2020; 28: 100583.
27. Velazquez M, Lee Y; for the Alzheimer’s Disease Neuroimaging Initiative. Random forest model for feature-based Alzheimer’s disease conversion prediction from early mild cognitive impairment subjects. PLoS One. 2021 Apr 29; 16(4): e0244773.
28. Al-Adhaileh MH. A long short-term memory biomarker-based prediction framework for Alzheimer’s disease. Sensors (Basel). 2022 Jan 31; 22(4): 1475.
29. Rahman AU, et al. A novel 3D-CNN with DAG framework for enhanced Alzheimer’s disease diagnosis using structural MRI. IEEE Conference. 2025 Feb 26.
30. Mahmud T, Barua K, Habiba SU, Sharmen N, Hossain MS, Andersson K. An explainable AI paradigm for Alzheimer’s diagnosis using deep transfer learning. Diagnostics (Basel). 2024 Feb 5; 14(3): 345.
31. AlexNet Alzheimer MRI model. Kaggle. 2022. Available from: https://www.kaggle.com/code/khaoulabc/alzheimer-mri-model-alexnet
32. Bahri A et al. Alzheimer’s multiclass classification using explainable AI techniques. Appl Sci. 2024 Sep 13; 14(18): 8287.
33. Kavitha C, Mani V, Srividhya SR, Khalaf OI, Tavera Romero CA. Early-stage Alzheimer’s disease prediction using machine learning models. Front Public Health. 2022 Mar 3; 10: 853294.
34. Khan MA et al. HSI-LFS-BERT: novel hybrid swarm intelligence based linguistic feature selection and computational intelligent model for Alzheimer’s detection using audio transcript. IEEE Access. 2022; 10: 117717-117732.
35. Prajapati R, Khatri U, Kwon GR. An efficient deep neural network binary classifier for Alzheimer’s disease classification. International Conference on Artificial Intelligence and Smart Systems (ICAIS); 2021: 204-209.
36. Mc Ardle R, Morris R, Hickey A, Del Din S, Koychev I et al. Gait in mild Alzheimer’s disease: Feasibility of multi-center measurement in the clinic and home with body-worn sensors: A pilot study. J Alzheimers Dis. 2020; 75(2): 559-570.
37. Den Haan J, Verbraak FD, Visser PJ, Bouwman FH. Retinal thickness in Alzheimer’s disease: A systematic

review and meta-analysis. Alzheimers Dement (Amst). 2020; 12(1): e12028.
38. Musiek ES, Holtzman DM. Mechanisms linking circadian clocks, sleep, and neurodegeneration. Science. 2016; 354(6315): 1004-1008.
39. Rentz DM, Dekhtyar M, Sherman J, Burnham S, Blacker D et al. The Feasibility of At-Home iPad Cognitive Testing for Use in Clinical Trials. J Prev Alzheimers Dis. 2016; 3(1): 8-12.
40. Paschalidis IC, Tandon A, Sun J et al. Predicting progression to Alzheimer's disease using speech patterns: A machine learning approach. Alzheimers Dement. 2024; 20(3): 512-521.
41. Lugito NPH, Djuwita R, Adisasmita A, Simadibrata M. Blood pressure lowering effect of Lactobacillus-containing probiotic. Int J Probiotics Prebiotics. 2022;17(1):1–13. Available from: https://www.nchpjournals.com/admin/uploads/ijpp2641-7197v17n1-1-13.pdf
42. Sharun K, Banu SA, Mamachan M, Abualigah L, Pawde AM, Dhama K. Unleashing the future: Exploring the transformative prospects of artificial intelligence in veterinary science. J Exp Biol Agric Sci. 2024;12(3):297–317. https://doi.org/10.18006/2024.12(3).297.317
43. Liu X, Wang Y, Zhang Y, et al. Gait analysis using wearable sensors for early detection of cognitive decline in Alzheimer's disease. Front Aging Neurosci. 2023; 15: 1182932.
44. Lim JK, Li QX, Villemagne VL, et al. Unlocking ocular biomarkers for early detection of Alzheimer's disease. Front Neurosci. 2024; 18: 11848398.
45. Coley N, Coste J, Andrieu S, et al. Sleep and activity patterns as digital biomarkers for early Alzheimer's disease: A prospective cohort study. Alzheimers Dement. 2022; 18(9): 1725-1737.
46. Alhasawi Y, Alghamdi S. Federated Learning for Decentralized DDoS Attack Detection in IoT Networks. IEEE Access. 2024; 12: 36132–36145.
47. Zhu X, Suk HI, Lee SW, Shen D. Subtype and stage inference of Alzheimer's disease by multi-task learning. Sci Rep. 2021; 11: 21630.