Received: 25 April 2025 | Revised: 5 August 2025 | Accepted: 17 October 2025 | Published online: 6 November 2025

REVIEW

Medinformatics
2025, Vol. 00(00) 1–12
DOI: 10.47852/bonviewMEDIN52026001

Precision Psychiatry: Leveraging Multi-omics and AI for Personalized Mental Health Treatment

Oluwafikayo Seun Adeyemi-Benson[1,*]

[1]*Department of Public Health, University of Illinois Springfield, USA*

Abstract: One of the main causes of the global disease burden is psychiatric disorders. However, due to the complex relationships between genetic, epigenetic, environmental, and neurological factors, diagnosing and treating these conditions remains challenging. Precision psychiatry, driven by multi-omics and artificial intelligence (AI), offers a novel approach to understanding mental health conditions and developing personalized treatments. This review examines the contributions of genome integration, transcriptomics, epigenomics, proteomics, metabolomics, and microbiome studies to psychiatric research and diagnosis. The area has changed as a result of recent developments in AI, particularly in machine learning and deep learning, combined with information from patient-reported outcomes, electronic health records, and neuroimaging. AI models facilitate the creation of customized treatment regimens, enhance pharmacogenomic predictions, and aid in the identification of biomarkers. Furthermore, the interpretability issues of these models are addressed by the emergence of explainable AI (XAI), which facilitates more transparent healthcare choices. The broad clinical application of precision psychiatry is, however, hindered by several challenges, including the difficulty in integrating multi-omics data, ethical concerns about the use of AI in mental health, and the need for thorough validation across diverse populations. Computational biologists, neuroscientists, psychiatrists, and clinicians from other disciplines must collaborate to address these challenges and develop scalable, reliable, and ethically sound frameworks for precision medicine in psychiatry. This study lays the groundwork for future research and clinical practice by highlighting the potential for integrating AI and multi-omics technology to revolutionize psychiatric care. Precision psychiatry can transition from a trial-and-error method to a tailored and predictive one by utilizing sophisticated computational tools, ultimately improving patient outcomes and mental health treatment. This study is among the first comprehensive efforts to explore the integration of multi-omics and AI, especially XAI, within the context of precision psychiatry, establishing a translational model for tailored mental health treatment.

Keywords: precision psychiatry, multi-omics, artificial intelligence, machine learning, biomarkers, pharmacogenomics, personalized medicine

1. Introduction

1.1. Overview of psychiatric disorders and limitations of conventional treatment

Psychiatric disorders such as major depressive disorder (MDD), schizophrenia, bipolar disorder, anxiety disorders, and post-traumatic stress disorder (PTSD) rank among the leading global causes of disability. These disorders originate from a complicated interplay between genetic, epigenetic, environmental, and neurological variables, making their diagnosis and treatment exceedingly problematic. Standard psychiatric treatment is still mostly imprecise and relies on symptom-based classification rather than underlying biological causes, despite significant advancements in neuroscience and psychopharmacology [1]. The absence of objective biomarkers for diagnosis and prognosis is one of the main problems with traditional psychiatric treatment. Psychiatric disorders are diagnosed by subjective clinical evaluations based on criteria from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) or the International Classification of Diseases (ICD-11), in contrast to other medical specialties where laboratory testing or imaging studies aid in diagnosis (e.g., blood glucose levels in diabetes). This emphasis on symptomatology leads to diagnostic variability and makes it harder to distinguish between overlapping disorders, which frequently results in incorrect diagnoses and treatment delays [2]. The inconsistent treatment response among mental patients is another important problem. The recommendation of psychotropic medications, such as mood stabilizers, antidepressants, and antipsychotics, is based more on trial and error than on personalized biological insights. According to studies, between 30% and 50% of people with depression do not experience remission after receiving initial treatment; instead, they require several drug trials, which prolongs their suffering and raises the possibility of adverse outcomes [3]. Additionally, several psychiatric medications have significant side effects that impact patient adherence and treatment effectiveness, such as metabolic syndrome, weight gain, sleepiness, and cognitive impairment [4].

Developing new medications is further hampered by the intricate neurological underpinnings of mental illnesses. Although studies have identified several neurotransmitter systems (such as glutamate, serotonin, and dopamine (DA)) that are connected to mental health issues, little is known about how psychiatric medications work. As a result, the development of new drugs in

*Corresponding author: Oluwafikayo Seun Adeyemi-Benson, Department of Public Health, University of Illinois Springfield, USA. Email: oadey2@uis.edu

psychiatry has been sluggish, and only a small number of novel treatments have entered clinical use in recent years [5]. Precision psychiatry, which combines multi-omics data, artificial intelligence (AI), and biomarker-driven methodologies to enhance diagnosis, predict therapeutic response, and provide more personalized medications, is urgently needed in light of these limitations. Precision psychiatry can enhance mental health care by leveraging advancements in genomics, transcriptomics, and neuroimaging to offer personalized and predictive treatment options, rather than a one-size-fits-all approach [6].

1.2. The need for precision medicine in psychiatry

Given the complexity of mental diseases and the shortcomings of conventional symptom-based diagnosis and treatment, precision medicine is essential in psychiatry. Unlike the traditional trial-and-error approach to selecting psychiatric drugs, precision psychiatry seeks to develop personalized treatment plans based on a patient's genetic makeup, molecular profiles, neurological traits, and environmental variables. One of the most significant problems facing psychiatry is the diversity of therapy responses [5]. For example, the effectiveness of mood stabilizers, antidepressants, and antipsychotics varies from person to person, and many patients experience treatment resistance or delayed therapeutic responses. Pharmacogenomic studies have demonstrated that genetic variations in medication target genes (e.g., HTR2A, SLC6A4) and drug-metabolizing enzymes (e.g., CYP2D6, CYP2C19) significantly impact therapeutic efficacy and adverse effect profiles [7]. Nevertheless, pharmacogenomic insights are rarely included in mental treatment guidelines, despite growing data, which results in subpar therapeutic outcomes [6].

In addition to pharmacogenomics, multi-omics techniques that include transcriptomics, proteomics, metabolomics, genomics, and epigenomics have the potential to identify biomarkers that can forecast the course, severity, and responsiveness to treatment of a disease. For instance, gene expression profiles linked to schizophrenia and major depressive illness have been discovered by transcriptome studies. Meanwhile, biomarkers based on neuroimaging provide information about anomalies in the structure and function of the brain associated with mental disorders [8]. By combining these biological datasets with AI and machine learning (ML) algorithms, it becomes easier to identify new therapeutic targets and improve diagnostic accuracy. Additionally, stress, nutrition, and the composition of the gut microbiome are examples of environmental and lifestyle factors that are crucial for maintaining mental health [9]. There are now new opportunities for microbiome-based treatments of mental illnesses since it has been shown that interactions between the host microbiota and the brain affect neurotransmitter synthesis, neuroinflammation, and brain function. The goal of precision psychiatry is to integrate these elements into a comprehensive predictive model that facilitates early disease detection and individualized preventive efforts [10]. Therefore, the transition to precision psychiatry signifies a paradigm change away from general and reactive treatment modalities and toward proactive, customized methods. By utilizing multi-omics technology, AI-driven analytics, and real-world clinical data, precision medicine has the potential to transform psychiatric care, enhance diagnosis, predict treatment outcomes, and improve overall patient outcomes. However, its practical implementation necessitates defined protocols, ethical considerations, and interdisciplinary teamwork to assure therapeutic utility and equal access [11].

The Role of Multi-Omics and AI in Transforming Mental Health Care

By enabling precision psychiatry and offering a deeper understanding of psychiatric diseases, the integration of multi-omics technology with AI revolutionizes mental health care. A thorough understanding of the biological processes underlying mental illnesses can be gained through the use of multi-omics techniques, including transcriptomics, proteomics, metabolomics, microbiomics, genomics, and epigenomics. For example, genomic studies have shown risk variants linked to depression and schizophrenia. At the same time, epigenetic alterations (such as DNA methylation and histone modifications) have been connected to illnesses brought on by stress. Likewise, metabolomic and microbiome studies reveal biochemical and gut–brain axis anomalies that cause mental disorders [12].

Notwithstanding these advancements, the amount and complexity of multi-omics data provide significant obstacles to clinical application and interpretation. Algorithms for AI and ML can revolutionize this. AI-driven models can combine diverse biological facts to identify predictive biomarkers, stratify patients based on molecular subtypes, and refine tailored treatment regimens. To accurately distinguish between psychiatric disorders, for instance, deep learning techniques have been applied to the analysis of neuroimaging data [13]. Furthermore, AI-driven diagnostic tools are becoming more transparent thanks to explainable AI (XAI), which enables clinicians to utilize them effectively in their practice. Psychiatry is shifting toward data-driven, precision-based therapies that enhance early diagnosis, predict therapeutic responses, and facilitate the identification of new therapeutic targets by leveraging multi-omics and AI. This interdisciplinary approach has the potential to improve patient outcomes and reduce the societal cost of psychiatric disorders by moving mental health treatment from a reactive model to a proactive and customized paradigm [14].

1.3. Methodology

Utilizing an integrative and systematic approach, this review investigates the contributions of AI and multi-omics to precision psychiatry. A thorough literature search was conducted using databases such as PubMed, Scopus, and Web of Science, with a focus on studies published within the previous five years (2019–2024). The following keywords were used: "precision psychiatry," "multi-omics," "machine learning in psychiatry," "AI-driven psychiatric diagnosis," and "biomarkers in mental health." Relevant studies were categorized into four key themes:

1) Challenges in conventional psychiatric treatment
2) Advancements in multi-omics research for psychiatric disorders
3) AI applications in biomarker discovery and personalized treatment
4) Prospects for precision psychiatry

High-impact research, systematic reviews, meta-analyses, and clinical trials proving the efficacy of precision medicine techniques were prioritized. The clinical usefulness, interpretability, and validity of current AI models in psychiatry were also evaluated. This methodical approach ensures a comprehensive and current synthesis of the latest developments in AI-driven psychiatry and multi-omics, providing valuable insights into the future direction of individualized mental health treatment.

The goal of this research is to compile the latest advancements in AI and multi-omics technologies that are impacting precision

psychiatry. By highlighting key developments in biomarker discovery, predictive modeling, and personalized treatment options, this study aims to bridge the gap between genetic research and clinical application, providing a comprehensive framework for the future of individualized mental health care.

1.4. Research gaps

Despite notable breakthroughs in these fields, there are still several research gaps in multi-omics and AI-driven precision psychiatry. First, repeatability across diverse populations is limited by the bulk of research's lack of clearly characterized molecular subtypes. This complicates the process of developing biomarkers because psychiatric disorders vary widely. Second, cross-study comparisons are challenging due to the lack of standardized data harmonization and interpretation techniques, despite the potential for multi-omics integration to provide thorough insights [8]. Furthermore, few of the AI models employed in psychiatric research have been evaluated in actual clinical settings, and the majority have poor generalizability and transparency. The lack of extensive, varied, and longitudinal datasets further hampers the creation of reliable predictive models. Further limiting the therapeutic application of AI-driven psychiatric tools are ethical considerations, namely, those pertaining to explainability, bias, and data privacy. Large-scale multicenter partnerships, enhanced data-sharing structures, and the use of XAI to guarantee clinical reliability are all necessary to close these gaps. Prospective biomarker validation, multi-omics AI pipeline optimization, and making precision psychiatry a practical reality in standard mental health care should be the main areas of future study [15].

2. Multi-omics in Precision Psychiatry

2.1. Genomics and transcriptomics

2.1.1. Genomics

By identifying genetic risk factors linked to mental diseases, genomic research has revolutionized psychiatric studies. Thousands of common genetic variations linked to disorders such as MDD, bipolar disorder, autism spectrum disorder (ASD), and schizophrenia have been identified by genome-wide association studies (GWAS). Instead of focusing on single-gene alterations, these investigations have brought attention to polygenic architectures, where several genetic loci contribute to disease vulnerability. Notable results include correlations with genes related to neurodevelopment (e.g., DISC1, brain-derived neurotrophic factor (BDNF)), dopaminergic pathways (e.g., DRD2), and synaptic transmission (e.g., CACNA1C, GRIN2A) [16]. To convert the results of GWAS into clinically useful instruments, polygenic risk scores (PRSs) were created. PRS assesses a person's genetic susceptibility to mental health conditions by combining the impacts of several genetic variants. Higher PRS levels have been linked to an increased risk of disease and have been shown to predict treatment responsiveness in conditions including schizophrenia and depression. However, because the majority of studies have been carried out in people of European ancestry, which lowers their predictive accuracy across a range of genetic backgrounds, ethnic bias in GWAS datasets currently limits the therapeutic utility of PRS. Furthermore, PRS by itself is not biologically interpretable, so in order to improve precision in psychiatric applications, it must be integrated with other omics layers [17].

2.1.2. Transcriptomics

Transcriptomics sheds light on the dynamic shifts in gene expression linked to mental illnesses, whereas genomic variants show genetic predisposition. Microarray-based expression profiling and RNA sequencing (RNA-seq) have identified dysregulated genes and pathways in parts of the brain linked to mental illnesses. In contrast to healthy controls, research has found that psychiatric patients exhibit abnormal expression of genes related to neuroinflammation (e.g., IL6, TNF-α), neurotransmitter systems (e.g., gamma-aminobutyric acid (GABA), serotonin pathways), and synaptic plasticity (e.g., postsynaptic density protein 95 (PSD-95), BDNF) [18]. Advances in single-cell RNA-seq have enabled scientists to examine variations in gene expression specific to individual cell types, thereby demonstrating the roles that various neuronal and glial cell populations play in psychiatric disorders. This method has linked immunological dysfunction to disease mechanisms by identifying astrocyte and microglia activation signatures in MDD and schizophrenia. Furthermore, expression indicators that predict individual variability in the efficacy of selective serotonin reuptake inhibitors (SSRIs) have been discovered by transcriptome investigations of antidepressant response. A more thorough understanding of mental illnesses is made possible by the integration of transcriptomics and genomics, which goes beyond static hereditary risk factors to functional molecular signals that can direct individualized treatment. To improve psychiatric therapies and refine predictive biomarkers, future research should prioritize combining multi-omics data, conducting longitudinal expression studies, and developing ML models [19].

2.1.3. Epigenomics

An understanding of epigenomics is crucial for comprehending the intricate relationships between genetic predisposition and environmental factors in psychiatric disorders. Unlike genetic variants, which are primarily static, epigenetic modifications are dynamic and responsive to ecological exposures, making them a potential avenue for personalized mental therapy. By coordinating changes in gene expression without altering the DNA sequence, the three primary epigenetic processes, DNA methylation, histone modifications, and non-coding RNA, have an impact on neurodevelopment, synaptic plasticity, and stress response pathways [4].

2.1.4. DNA methylation in psychiatric disorders

DNA methylation, the most extensively studied epigenetic modification, involves the addition of methyl groups to cytosine residues at CpG sites, typically leading to gene silencing. Altered methylation patterns have been linked to several psychiatric conditions:

Schizophrenia: Differential methylation of genes involved in synaptic function (e.g., GRIN2B, GAD1) and dopaminergic signaling (e.g., DRD2) has been reported in postmortem brain tissues of schizophrenia patients.

Depression: BDNF (brain-derived neurotrophic factor) hypomethylation has been linked to a higher risk of developing depression, especially in people who experienced stress early in life.

Bipolar disorder: Mood instability has been linked to dysregulated methylation of the CLOCK and PER genes, which control circadian rhythms.

Stress, trauma, and medication exposure may cause long-lasting methylation alterations, according to longitudinal research, supporting the idea that environmental variables play a part in the development of disease.

2.1.5. Histone modifications and chromatin remodeling

Histone modifications influence chromatin structure and gene accessibility, regulating transcriptional activity. The modifications comprise acetylation, methylation, phosphorylation, and ubiquitination of histone tails. Histone acetylation, facilitated by histone acetyltransferases, generally enhances gene activation by relaxing chromatin structure. In contrast, histone deacetylation, carried out by histone deacetylases (HDACs), suppresses gene expression. Meanwhile, histone methylation exhibits context-dependent outcomes, activating or inhibiting gene transcription depending on the specific histone residue and methylation level. Altered histone modification patterns have been observed in psychiatric disorders. For example, decreased histone acetylation in BDNF promoters has been linked to reduced neuroplasticity in depression. Interestingly, HDAC inhibitors are being explored as potential epigenetic-based therapeutics for mood disorders [20].

2.1.6. Environmental influences on the epigenome

Environmental exposures prenatal stress, early-life adversity, diet, substance abuse, and social stressors can induce long-term epigenetic changes that predispose individuals to psychiatric conditions: Childhood trauma has been associated with hypermethylation of the NR3C1 gene encoding the glucocorticoid receptor results in a dysregulated hypothalamic–pituitary–adrenal (HPA) axis response and increased risk of depression and PTSD. Maternal stress during pregnancy has been linked to altered fetal methylation of neurodevelopmental genes, increasing vulnerability to ASD and schizophrenia [21]. Substance abuse, including alcohol and opioids, has been shown to induce lasting epigenetic changes in DA-related genes, contributing to addiction and psychiatric comorbidities. Epigenomic markers provide a dynamic and reversible layer of regulation, offering new avenues for biomarker discovery and therapeutic targeting. Advances in epigenome-wide association studies, single-cell epigenomics, and ML-based epigenetic modeling are refining our ability to link specific modifications to psychiatric phenotypes. Future precision medicine strategies may incorporate epigenetic profiling to predict disease risk, optimize treatment response, and develop novel epigenetic therapies tailored to individual patients [22].

2.2. Proteomics and metabolomics

Proteomics and metabolomics, which offer a dynamic understanding of the molecular mechanisms underlying mental diseases, are increasingly significant precision components of psychiatry. While transcriptomics and genomics reveal genetic predispositions and shifts in gene expression, proteomics and metabolomics provide real-time pictures of biochemical processes in disease states and treatment responses. By identifying particular biomarkers, these techniques support patient classification, early diagnosis, and tailored therapeutic interventions in mental health care. Figure 1 illustrates the precision psychiatry framework [23], which begins with a comprehensive phenotypic profile that considers behavioral, biological, and environmental aspects. It demonstrates how the provision of individualized treatment decisions is made possible by patient classification according to underlying physiology. Ultimately, this approach enhances diagnostic accuracy, therapeutic efficacy, and our understanding of the mechanisms underlying mental diseases [11].

2.2.1. Proteomics in psychiatric disorders

Proteomics involves the extensive study of proteins and the examination of their structure, function, and modifications. Within psychiatry, proteomic studies have uncovered significant

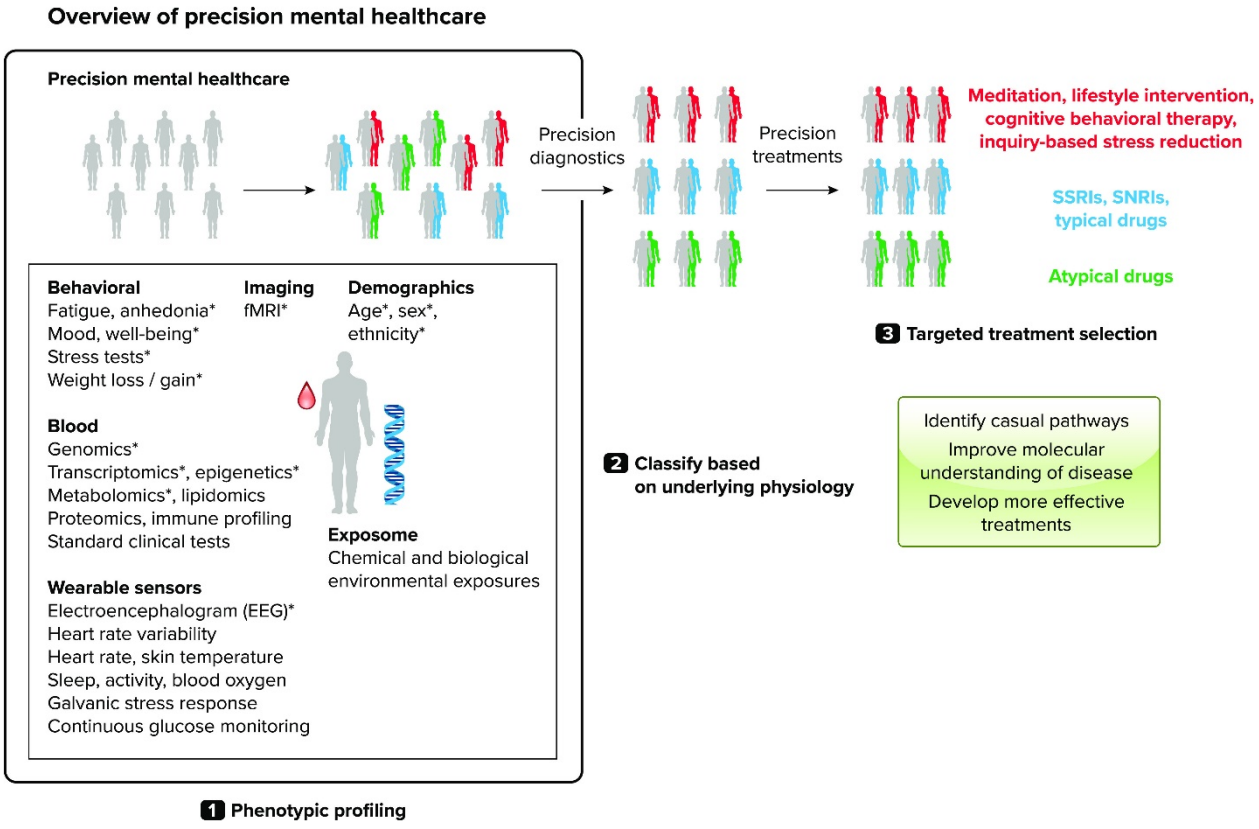

Figure 1. Overview of precision mental healthcare

molecular signatures linked to disorders like schizophrenia, MDD, bipolar disorder, and ASD. According to several studies, these disorders may arise from the dysregulation of proteins associated with oxidative stress, neuroinflammation, neurotrophic factors, and synaptic processes. Psychiatric patients typically exhibit increased levels of neuroinflammation-related proteins, such as C-reactive protein (CRP), interleukins (IL-6, IL-1β), and tumor necrosis factor-alpha (TNF-α), suggesting an immune system imbalance that may accelerate the disease course [24]. Similarly, deficiencies in neuroplasticity seen in depression and schizophrenia have been linked to alterations in the amounts of neurotrophic factors, including glial cell line-derived neurotrophic factor, BDNF, and nerve growth factor. Furthermore, synaptic dysfunction in schizophrenia and ASD has been linked to anomalies in synaptic proteins, including synaptophysin, PSD-95, and neurexins. Finally, mood disorders exhibit dysregulation of oxidative stress indicators such as glutathione peroxidase, malondialdehyde, and superoxide dismutase, indicating a connection to mitochondrial dysfunction in their pathophysiology. Additionally, proteomics has shown promise in forecasting therapy response [25]. Studies have shown that psychiatric medications, such as antidepressants and antipsychotics, modulate protein expression profiles, suggesting that specific protein biomarkers could guide drug selection and minimize adverse effects. Advances in mass spectrometry-based proteomics now enable the identification of novel biomarkers that may serve as diagnostic tools and therapeutic targets in mental health care [3, 24].

2.2.2. Metabolomics in psychiatry

Metabolomics, the comprehensive investigation of small-molecule metabolites, provides insights into the altered metabolic processes associated with psychiatric disorders. Since metabolites are the final products of biological processes, they are directly regulated by genetic, environmental, and lifestyle variables. Several metabolic changes have been reported in psychiatric illnesses, revealing prospective diagnostic and therapeutic targets. One of the areas of psychiatric metabolomics that has been studied the most is neurotransmitter metabolism. Patients with anxiety disorders, schizophrenia, and depression have been found to have altered amounts of neurotransmitters, including GABA, DA, norepinephrine, and serotonin [26]. The discovery of anomalies in phospholipid and sphingolipid metabolism through lipidomics research underscores the crucial role that membrane lipid composition plays in the development of mental disorders. Moreover, both bipolar disorder and schizophrenia are associated with mitochondrial dysfunction due to abnormalities in energy metabolism, such as changed levels of pyruvate, lactate, and tricarboxylic acid cycle intermediates [27]. The importance of gut-derived metabolites, such as short-chain fatty acids (SCFAs), metabolites from the kynurenine pathway, and indole derivatives, which are essential for neuroinflammation and neurotransmission, has also been highlighted by recent research showing a strong association between mental health disorders and gut microbiota. These findings demonstrate how metabolomics can help clarify gut–brain relationships and inform the development of microbiome-based therapies for mental health issues [28].

2.2.3. Clinical and translational implications

Integrating proteomics and metabolomics into psychiatric research could have a significant positive impact on precision medicine. By identifying accurate biomarkers, these methods can enhance therapy stratification, facilitate real-time tracking of disease progression, and expedite early diagnosis. Additionally, the discovery of metabolic and proteomic indicators associated with treatment response could lead to customized medication, reducing the need for psychiatric trial-and-error dosing. Developments are quickly improving the sensitivity and specificity of biomarker identification in nuclear magnetic resonance spectroscopy and mass spectrometry, as well as AI-driven multi-omics integration [29]. However, extensive validation studies are essential before these findings can be applied in routine clinical practice. Future research should aim to develop standardized procedures for biomarker evaluation and integrate proteomic and metabolomic data with other omics to achieve a comprehensive understanding of psychiatric disorders. Table 1 highlights key contributions of various multi-omics methods in uncovering the genetic basis of psychiatric illnesses and their potential clinical applications in precision psychiatry [12].

Table 1. Summary of multi-omics contributions to psychiatry

Omics Type	Key Findings	Psychiatric Disorders	Clinical Applications	Clinical Validation Stage
Genomics	Identification of risk loci via GWAS; polygenic risk scoring	Schizophrenia, bipolar disorder, major depressive disorder	Genetic predisposition prediction, patient stratification, personalized intervention strategies	Early clinical use (e.g., PRS-based tools in pilot studies)
Transcriptomics	Dysregulation of synaptic and inflammatory genes in brain tissue	Schizophrenia, autism spectrum disorders	Molecular subtyping, treatment response prediction	Research stage
Epigenomics	DNA methylation and histone modifications influenced by stress and trauma	PTSD, depression, anxiety disorders	Epigenetic biomarker development, understanding gene–environment interactions	Experimental validation (e.g., methylation panels in cohorts)
Proteomics	Altered synaptic and inflammatory protein levels in blood and cerebrospinal fluid	Schizophrenia, MDD, Alzheimer's disease	Peripheral biomarker discovery, treatment monitoring	Research stage
Metabolomics	Metabolic alterations in neurotransmitter pathways and energy metabolism	Bipolar disorder, depression	Metabolic biomarker identification, therapeutic response evaluation	Experimental validation
Microbiomics	Gut–brain axis dysbiosis linked to neuroinflammation and behavior changes	Autism, depression, anxiety	Microbiome-targeted therapies, adjunct treatment strategies	Early clinical exploration (e.g., probiotics in trials)

2.3. Microbiome

The gut microbiota profoundly affects brain function and mental health through the gut–brain axis, a two-way communication mechanism that involves the neurological, immunological, and endocrine systems. New research reveals that changes in gut microbial composition alter neurodevelopment, neurotransmitter management, and inflammatory responses, consequently playing a role in psychiatric illnesses such as depression, anxiety, schizophrenia, and ASD. Dysbiosis, an imbalance in gut microbiota, is associated with increased intestinal permeability, which in turn leads to systemic inflammation and neuroinflammation. Certain bacteria, such as *Lactobacillus* and *Bifidobacterium*, generate neurotransmitters, including GABA and serotonin, which help control mood and behavior [30]. Reduced levels of these beneficial microorganisms have been seen in persons with depression and anxiety, indicating a potential relationship between the microbiome makeup and psychiatric symptoms.

Alterations in microbial metabolites, such as SCFAs and intermediates of the kynurenine pathway, have been connected to bipolar illness and schizophrenia. SCFAs, especially butyrate and propionate, are crucial for controlling neuroinflammation and maintaining the blood-brain barrier's integrity. Disturbances in these metabolites may lead to mood swings and cognitive decline. Furthermore, by impairing stress responses, microbial interactions with the HPA axis may make mental diseases worse. Recent research has examined microbiome-targeted therapies, such as fecal microbiota transplantation, probiotics, and prebiotics, to enhance mental health outcomes and restore gut microbial equilibrium [31]. Despite encouraging first findings, more investigation is needed to identify certain microbial indicators and show the causal relationships between gut microbiota and mental health disorders. Combining microbiome analysis with other omics data may help advance microbiome-based precision psychiatry and provide a more thorough understanding of the pathophysiology of mental health.

3. AI in Psychiatry

3.1. Machine learning and neuroimaging

The application of AI and ML in neuroimaging has revolutionized psychiatric research, providing scientists with valuable tools for identifying mental health conditions and developing reliable biomarkers. There are typically no clear-cut molecular markers for disorders, including schizophrenia, MDD, bipolar disorder, and ASD; hence, clinical evaluations are mainly used for diagnosis. ML-based neuroimaging analysis, on the other hand, offers an objective method of detecting structural and functional brain abnormalities associated with mental disorders, increasing the accuracy of diagnosis and available treatments [32]. Advances in neuroimaging technology, including positron emission tomography, diffusion tensor imaging, magnetic resonance imaging (MRI), and functional MRI (fMRI), provide accurate information on the brain's structure, connections, and metabolic activity. Massive imaging datasets can be analyzed by AI algorithms and advanced learning techniques, such as recurrent neural networks (RNNs) and convolutional neural networks (CNNs), to identify patterns associated with mental illnesses. For example, ML models have identified changes in amygdala activity in depressed individuals, cortical thinning in schizophrenia patients, and altered white matter networks in bipolar individuals. These findings highlight the potential use of neuroimaging biomarkers in conjunction with clinical assessments to provide earlier and more precise diagnoses [32].

Based on neuroimaging data, supervised ML algorithms such as support vector machines, random forests, and deep neural networks have demonstrated remarkable accuracy in differentiating between psychiatric patients and healthy controls. ML algorithms that analyze fMRI data have identified disrupted connectivity in the default mode network in individuals with schizophrenia. In self-referential cognition, this brain network is essential. The amygdala of those with anxiety disorders also exhibits increased activity, according to AI-based assessments of resting-state fMRI. The foundation for data-driven diagnostic systems that reduce reliance on subjective symptom reporting is established by these AI-driven classifications [33]. Furthermore, by revealing neurobiological diversity, ML techniques might help subtype mental illnesses. For example, studies using unsupervised clustering algorithms have identified different neuroimaging-based groups within depression, each exhibiting distinct patterns of brain connections and treatment responses. By matching patients' brain patterns to specific medicines, this classification can improve precision psychiatry [33]. To train AI-driven ML models, Figure 2 presents a comprehensive architecture that integrates neuroimaging, clinical data, and multi-omics (including genomics, transcriptomics, proteomics, and metabolomics) [34]. Ultimately, this comprehensive strategy enhances precision diagnostics and personalized treatment options in neuropsychiatry by facilitating the discovery of novel therapeutic targets, patient-specific models, and predictive biomarkers.

AI plays a crucial role in developing predictive biomarkers for the effectiveness of therapy and aids in diagnosis. Numerous psychiatric medications, such as antidepressants and antipsychotics, have inconsistent results, which might occasionally necessitate lengthy dose trials. Individual treatment outcomes have been predicted using ML models that integrate neuroimaging data with clinical and genetic information [35]. AI-based evaluations of initial fMRI connectivity, for instance, can effectively distinguish between people who react well to SSRIs, which are used to treat depression, and those who do not. Similarly, ML techniques have been used to predict lithium reactions in bipolar disorder patients using electroencephalography (EEG) and MRI data. Apart from medication-based treatments, the effectiveness of neuromodulation techniques, such as electroconvulsive therapy and transcranial magnetic stimulation, is also evaluated using AI-enabled neuroimaging analysis. AI improves patient selection and reduces the risks of unsuccessful therapy by identifying brain signals associated with positive responses to different therapies [36].

3.2. Natural language processing (NLP)

In psychiatry, natural language processing (NLP), a subfield of AI, has emerged as a crucial instrument for deriving and producing insightful information from unstructured text data. NLP offers an objective and scalable approach to processing clinical documents, electronic health records (EHRs), and patient-reported data because of the complexity of mental illnesses and the subjective reporting of symptoms. Researchers and medical professionals can increase the precision of diagnoses, track the course of illnesses, and create individualized treatment plans by using NLP [37]. Significant amounts of unstructured data, including doctors' notes, diagnostic summaries, medication diaries, and psychological evaluations, are found in EHRs. To identify patterns indicative of mental health issues, NLP algorithms effectively extract key information from these records. For instance, by examining

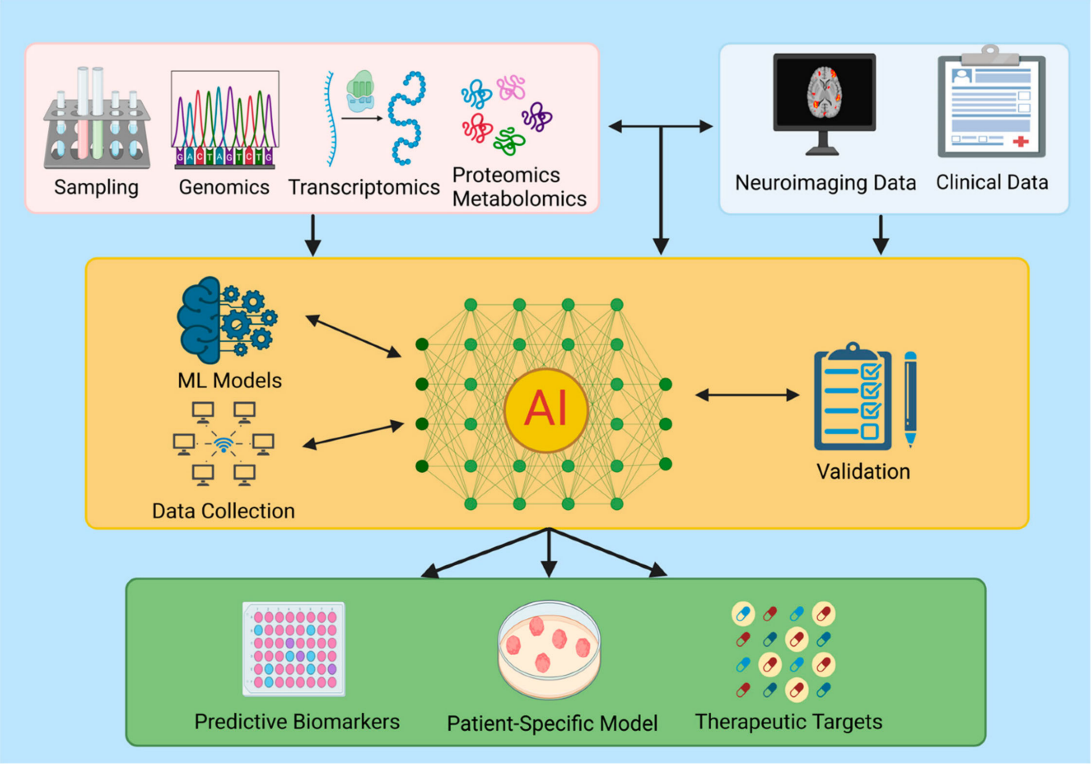

Figure 2. Integration of multi-omics and AI in neuropsychiatric precision medicine

linguistic clues in clinical data, NLP models have been used to identify early indicators of schizophrenia and depression. A patient's mental condition can be inferred from confident word choices, sentence constructions, and emotional indicators, which may allow for earlier intervention [38]. NLP also enables automated phenotyping, where ML models classify mental illnesses based on patient histories and clinical descriptions. This method enhances reproducibility in psychiatric research, streamlines the standardization of diagnosis, and reduces clinician variability.

Additionally, by identifying signs of suicidal ideation, self-harm, or extreme mood swings in clinical data, NLP-based systems can identify high-risk patients and enable timely intervention [39]. NLP is being increasingly used to examine patient-reported outcomes, including social media posts, discussions with chatbots or virtual mental health assistants, and self-assessments, in addition to clinical information. Research indicates that mental health disorders like anxiety and depression are associated with linguistic traits like the use of more self-referential language, simpler sentence structures, and a preponderance of words that express negative emotions. Researchers can now continuously track a patient's mental health thanks to AI-driven sentiment analysis and topic modeling [40]. NLP's use in psychiatry has benefits, but there are drawbacks as well, including issues with biases in training data, model openness, and data privacy. Strict adherence to ethical norms is necessary when handling sensitive patient data to comply with laws such as the Health Insurance Portability and Accountability Act (HIPAA) and the General Data Protection Regulation (GDPR). Furthermore, NLP systems that are based on skewed datasets run the danger of escalating already-existing inequities in mental health diagnosis and care. To address these issues, initiatives such as XAI, which aim to enhance model transparency and fairness, are crucial. In the future, combining NLP with multi-omics information and neuroimaging results may lead to a more comprehensive understanding of mental illnesses [41]. Furthermore, preventive therapies could be made possible by real-time NLP technology in digital psychiatry, which would lessen the financial strain that mental illness places on healthcare systems. NLP holds considerable promise for developing precision psychiatry and enhancing patient outcomes by increasing the precision and accessibility of psychiatric assessments.

3.3. Explainable AI

By providing data-driven insights that improve diagnosis, risk prediction, and therapy optimization, AI has changed psychiatric research and clinical practice. However, the "black-box" nature of many ML models, which usually lack transparency and interpretability, presents challenges for the widespread use of AI in psychiatry. This problem is addressed by Explainable AI (XAI), which makes AI-driven decisions more transparent and understandable, allowing patients, researchers, and doctors to trust and utilize AI-generated insights efficiently. Explainability is especially crucial in psychiatry, where judgments depend primarily on subjective evaluations, patient-reported symptoms, and extensive, heterogeneous datasets [32]. A significant issue with AI in psychiatry is the lack of transparency in deep learning models, which can identify patterns in data but fail to explain the reasons behind their predictions. This lack of transparency may inhibit clinical integration, as healthcare professionals are reluctant to implement AI-generated recommendations without a precise understanding of the underlying rationale. For instance, if an AI model anticipates a high suicide or schizophrenia risk, psychiatrists demand clarity on whether this prognosis is based on genetic variables, neuroimaging results, behavioral signs, or a blend of these elements. AI models can lead to diagnostic uncertainty or increase biases entrenched in training datasets without transparency [42].

Several ways have been proposed to enhance the explainability of AI models in psychiatry. Techniques for feature attribution, including SHAP (Shapley Additive Explanations) and LIME (Local Interpretable Model-agnostic Explanations), help clinicians pinpoint the key factors – such as genetic variations, neuroimaging irregularities, and linguistic markers – that most significantly affect a specific case prediction. Furthermore, rule-based and decision tree models offer more clarity than deep learning methods as they present explicit decision-making paths that physicians can easily understand. Attention mechanisms in deep learning are also applied in neuroimaging studies, enabling investigators to focus on specific brain areas associated with mental health issues [35]. Beyond interpretability, ethical considerations must be taken into account to ensure the proper use of AI in psychiatry. A significant concern is bias in AI models, which can arise from training data that fails to represent diverse populations accurately. Training AI systems based on data from particular demographic groups might lead to inaccurate or biased predictions for underrepresented persons, increasing mental health inequities. Additionally, privacy and data security are especially crucial in psychiatry due to the sensitive nature of patient information. Adhering to data protection standards and establishing secure, anonymized AI systems are vital for sustaining patient trust [43].

A fundamental ethical challenge is guaranteeing patient autonomy and informed consent in AI-supported psychiatric care. Both patients and clinicians require a comprehensive understanding of how AI algorithms generate predictions and recommendations. Explainable AI enhances collaborative decision-making by providing explicit insights into risk factors and treatment alternatives, ensuring that AI serves as a supportive tool rather than a substitute for clinical judgment [44]. To advance the field of XAI in psychiatry, future studies should focus on constructing hybrid models that combine deep learning with interpretable statistical methods, thereby achieving high accuracy and transparency. Furthermore, regulatory frameworks should be built to define requirements for AI explainability, bias reduction, and the ethical deployment of AI in mental healthcare situations. By emphasizing interpretability and moral dimensions, XAI can establish trust in AI-driven psychiatric solutions, ultimately boosting patient outcomes and furthering precision psychiatry [42].

4. Biomarkers and Drug Development

4.1. Identification of molecular markers for psychiatric disorders

Identifying molecular biomarkers for psychiatric disorders is essential for advancing precision psychiatry. Unlike other medical conditions that have clear biological markers, disorders like schizophrenia, MDD, and bipolar disorder have typically been diagnosed based on clinical interviews and symptom criteria. This dependence on subjective evaluation has led to difficulties in accurate diagnosis, treatment choices, and prognosis. Recent advancements in multi-omics technologies – including genomics, transcriptomics, proteomics, metabolomics, and epigenomics – are now facilitating the identification of objective molecular markers that can enhance diagnostic accuracy and inform personalized treatment approaches [45]. Genomic research, particularly GWAS, has uncovered various genetic variants linked to psychiatric disorders. For example, PRSs derived from GWAS findings have shown potential in forecasting an individual's genetic predisposition to disorders like schizophrenia and depression. Nonetheless, the complex polygenic nature of these conditions suggests that no single genetic variant can entirely account for disease risk. Integrating transcriptomic data – which shows changes in gene expression in the brain and other tissues – provides deeper insight into the molecular mechanisms of psychiatric disorders. Irregular gene expression patterns are associated with neuronal dysfunction, alterations in synaptic plasticity, and the immune system's role in mental health conditions [46].

By providing data-driven insights that improve diagnosis, risk prediction, and therapy optimization, AI has changed psychiatric research and clinical practice. However, the "black-box" nature of many ML models, which usually lack transparency and interpretability, presents challenges for the widespread use of AI in psychiatry. This problem is addressed by explainable AI (XAI), which makes AI-driven decisions more transparent and understandable, allowing patients, researchers, and doctors to trust and utilize AI-generated insights efficiently. By identifying and validating dependable molecular markers, precision psychiatry can advance toward personalized interventions that enhance patient outcomes and minimize the trial-and-error nature of psychiatric treatment [23]. Recent advances in large-scale deep learning models, including transformer-based architectures and graph neural networks, have enabled more robust biomarker discovery by integrating genomic, transcriptomic, and neuroimaging data. While these models offer powerful pattern recognition capabilities, limitations such as poor generalizability, interpretability, and the need for large, annotated datasets remain significant challenges. These constraints underscore the need for cross-validation and clinical benchmarking to translate computational findings into actionable psychiatric biomarkers [47]. Table 2 presents essential validated biomarkers for psychiatric disorders, highlighting their relevance for diagnosis, prognosis, and treatment, as well as their current stage of research or clinical use.

4.2. AI-driven pharmacogenomics and personalized treatment strategies

AI and pharmacogenomics merge to transform psychiatric care by offering personalized drug treatments tailored to an individual's genetic makeup. Psychiatric conditions like depression, schizophrenia, and bipolar disorder show significant differences in how patients respond to therapy, sometimes leaving them to cope with side effects or ineffective symptom management.

Table 2. Psychiatric biomarkers and their clinical relevance

Biomarker Type	Disorder	Clinical Utility	Current Status
BDNF (protein)	Major depressive disorder	Indicator of disease severity and treatment response	Research
S100B (protein)	Bipolar disorder	Marker of astrocyte activity and blood-brain barrier damage	Research
miR-134 (miRNA)	Schizophrenia	Potential diagnostic biomarker	Research
FKBP5 (gene)	PTSD	Predictor of stress response and treatment response	Clinical use (limited)
CRP (protein)	Depression, schizophrenia	Inflammatory marker associated with symptom severity	Research
Cortisol (hormone)	Depression, PTSD	Indicator of HPA axis dysregulation	Clinical use (limited)

Conventional psychiatric drugs frequently use a trial-and-error method, which can prolong patient suffering and raise medical expenses [8]. AI-driven pharmacogenomics offers a data-driven method that optimizes drug selection and dosage for every patient by analyzing genetic, transcriptomic, and clinical data using ML algorithms. Pharmacogenomics research has discovered genetic variations in transporters, neurotransmitter receptors, and drug-metabolizing enzymes that impact how people react to psychiatric drugs. The metabolism of frequently prescribed antidepressants and antipsychotics, for example, might be changed by polymorphisms in cytochrome P450 (CYP) genes, such as CYP2D6 and CYP2C19. Ultra-rapid metabolizers may need higher doses to produce therapeutic effects, while patients with particular genotypes of poor metabolizers may incur more severe medication toxicity [48]. These genetic characteristics can be combined with other biological and clinical information using AI algorithms to forecast a person's reaction to medicine more precisely.

To identify patterns associated with treatment outcomes, large pharmacogenomic datasets have been analyzed using ML, deep learning, and decision trees. These AI systems examine intricate connections between comorbidities, demographics, medication histories, and genetic markers to give doctors evidence-based treatment recommendations. Improving personalized psychiatry, NLP techniques extract key information from EHRs and patient-reported data, increasing prediction accuracy in treatment response models [49]. Beyond pharmacogenomics, AI also helps identify new drug targets and repurpose existing drugs for the treatment of psychiatric disorders. Deep learning algorithms that utilize multi-omics data uncover previously unknown biochemical pathways associated with psychiatric conditions, aiding the development of targeted therapies. Additionally, AI-powered virtual screening accelerates the identification of candidate compounds with strong binding affinity to critical neuropsychiatric targets, speeding up the drug discovery process [50].

While progress has been made, bringing AI-driven pharmacogenomics into routine clinical use still faces significant challenges. Key concerns, including data privacy, model interpretability, and the need for broad and diverse datasets, must be addressed to ensure the reliability and applicability of AI predictions. Additionally, developing multidisciplinary collaboration among bioinformaticians, psychiatrists, and pharmacologists is essential for refining AI algorithms and confirming their therapeutic relevance. Future work in AI-driven pharmacogenomics should focus on developing robust and transparent models that incorporate genetic, epigenetic, and environmental factors to provide comprehensive therapy recommendations. Precision psychiatry can advance toward completely customized treatments by utilizing AI's analytical powers, which will also lessen unfavorable drug reactions and enhance therapeutic results for patients with mental illnesses [51]. Core ML techniques are frequently used in AI models used in psychiatric research. To predict outcomes, such as the diagnosis of an illness or the response to treatment, supervised learning involves training algorithms on labeled datasets. On the other hand, unsupervised learning techniques, such as clustering, can identify patient subgroups or underlying patterns without the need for labels. Complex nonlinear correlations in high-dimensional data, such as transcriptome profiles or neuroimaging, are captured by artificial neural networks and their deep learning extensions, such as CNNs and RNNs. It is easier to choose, adjust, and understand AI technology in psychiatric practice when one is aware of these modeling notions.

5. Challenges and Future Directions

5.1. Data integration, ethical concerns, and clinical implementation barriers

Significant problems with data integration, ethical difficulties, and therapeutic application arise when multi-omics and AI are included in precision psychiatry. Even while ML and genetic technology have advanced, there are still a number of obstacles that must be overcome before these developments may be effectively incorporated into standard psychiatric treatment. It can be difficult to integrate many biological data types, such as transcriptomics, proteomics, metabolomics, genomes, and microbiome information. The quantity, structure, and quality of these diverse datasets vary, making it challenging to develop cohesive models that can accurately forecast psychiatric outcomes [34]. Predictive models must also take behavioral, social, and environmental health factors into account because psychiatric disorders are impacted by complex gene–environment interactions. Although AI methods like deep learning and network-based algorithms show promise in handling multimodal data, obtaining large, high-quality datasets is still a significant challenge. The small sample sizes and lack of diversity in many current psychiatric studies constrain the utility of AI-driven predictions. Using AI and multi-omics data in psychiatry raises a number of important ethical issues. Given that genetic and medical records contain sensitive personal data, privacy and data security are essential [52]. Maintaining patient anonymity requires adherence to regulations like HIPAA and the GDPR. Furthermore, algorithmic bias poses a risk to precision psychiatry, particularly when AI models are built with non-representative datasets. ML algorithms that are biased may prescribe different diagnoses and treatments, which could be harmful to underrepresented groups. The implementation of bias detection technology, careful dataset curation, and making sure that diverse populations are included in psychiatric research are all necessary to address this challenge [53].

Several real-world obstacles exist to the adoption of AI-driven precision psychiatry. There is skepticism and resistance in clinical settings since many psychiatrists and other medical professionals lack competence in AI and multi-omics technology. Furthermore, standardization of AI models, regulatory approval, and validation through comprehensive clinical studies are necessary for incorporating AI-based decision support systems into existing healthcare frameworks. The practical implementation of precision psychiatry will be significantly hindered by the lack of precise standards and evidence of therapeutic efficacy [54]. Future work should focus on developing robust frameworks for integrating multi-omics data, ensuring the ethical use of AI, and promoting increased collaboration between regulatory bodies, physicians, and computer scientists to address these challenges. Research and clinical practice can be more closely aligned by investing in XAI models and creating multidisciplinary training programs. Precision psychiatry can advance toward offering patients with psychiatric diseases individualized, data-driven treatments by overcoming these obstacles [12].

5.2. Future potential of AI and multi-omics in psychiatry

The use of AI and multi-omics in psychiatry has the potential to revolutionize the diagnosis, treatment, and management of mental diseases. Future advancements in these fields are expected to

enhance precision psychiatry by facilitating more accurate disease classification, personalized treatment regimens, and improved mental health disorder prediction models. One noteworthy area of innovation that can provide a deeper understanding of the brain's composition and operation is deep learning-based neuroimaging analysis. AI models that leverage large imaging datasets, such as fMRI and EEG, can find novel biomarkers for mental diseases, enhancing early diagnosis and treatment strategies [8]. More accurate symptom grading and continuous mental health monitoring will also be made possible by advancements in NLP, which will facilitate the identification of clinically significant patterns in patient-reported data, EHRs, and social media interactions. Multi-omics methodologies are expected to progress, especially in the fields of epigenomics, PRS, and gut microbiome research. Improved PRS, enabled by larger genomic datasets and improved computational methods, would allow psychiatrists to evaluate an individual's genetic risk for diseases such as MDD, bipolar disorder, and schizophrenia. Furthermore, an increasing amount of evidence indicates that epigenetic abnormalities, like DNA methylation and histone modifications, have a significant impact on the pathophysiology of mental illnesses. AI-powered models that combine transcriptome, proteome, and epigenomic data should facilitate the identification of novel treatment targets and enhance patient group stratification in clinical trials [55]. The future of psychiatry will undoubtedly involve multi-omics-based pharmacogenomics, resulting in more personalized treatment regimens. AI-driven pharmacogenomic frameworks will facilitate the precise selection of drugs tailored to an individual's genetic and molecular traits, enhancing therapeutic efficacy while minimizing adverse effects. This technique promises to alter psychiatric drug administration, especially for complex situations like refractory depression and schizophrenia [56].

Furthermore, improvements in AI-driven wearable technology and digital phenotyping will permit the real-time tracking of behavioral and physiological markers, generating new options for early intervention and individualized mental health care. AI-powered chatbots and virtual mental health assistants could also give scalable, accessible mental health support, supplementing traditional psychiatric care. To effectively leverage these achievements, continuous investment in large-scale, multi-omics databases, ethical AI frameworks, and interdisciplinary collaboration is necessary. By mixing cutting-edge computational tools with biological insights, the future of precision psychiatry holds promise for a shift toward proactive, personalized, and data-driven mental health care [50].

6. Conclusion

This paper presents a strategic perspective on how multi-omics technologies and AI are changing precision psychiatry. Researchers are uncovering complex biological signals that enhance our understanding of psychiatric pathophysiology by integrating genomic, transcriptomic, epigenomic, proteomic, metabolomic, and microbiome data. AI tools, such as ML in neuroimaging, NLP of clinical records, and AI-guided pharmacogenomics, are increasing the creation of prediction models and individualized treatment approaches. Although these methods hold enormous potential, their clinical use faces problems such as data uniformity, algorithmic openness, and inadequate external validation. Therefore, our study highlights the importance of conducting substantial, diversified, and long-term research to validate multi-omics biomarkers and AI models in real-world psychiatric populations. Additionally, ethical and technological challenges, including privacy concerns, bias reduction, and model interpretability, require careful consideration. Future research should focus on strong model validation, interdisciplinary collaboration, and the construction of standardized pipelines for clinical implementation. As these problems are resolved, precision psychiatry is developing from a promising concept to a realistic reality, resulting in more effective, evidence-based, and patient-centered mental health care. Precision psychiatry, driven by advancements in multi-omics and AI, has the potential to revolutionize mental health treatment by shifting away from symptom-based approaches and toward biologically based, personalized interventions that improve treatment outcomes, enhance diagnostic accuracy, and ultimately improve patient care.

Ethical Statement

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

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

The data supporting the findings of this study are available upon request from the corresponding author.

Author Contribution Statement

Oluwafikayo Seun Adeyemi-Benson: Conceptualization, Methodology, Software, Validation, Writing – original draft, Writing – review & editing.

References

[1] GBD 2019 Mental Disorders Collaborators. (2022). Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet Psychiatry*, *9*(2), 137–150. https://doi.org/10.1016/S2215-0366(21)00395-3

[2] Abi-Dargham, A., Moeller, S. J., Ali, F., DeLorenzo, C., Domschke, K., Horga, G., …, & Krystal, J. H. (2023). Candidate biomarkers in psychiatric disorders: State of the field. *World Psychiatry*, *22*(2), 236–262. https://doi.org/10.1002/wps.21078

[3] McIntyre, R. S., Alsuwaidan, M., Baune, B. T., Berk, M., Demyttenaere, K., Goldberg, J. F., …, & Maj, M. (2023). Treatment-resistant depression: Definition, prevalence, detection, management, and investigational interventions. *World Psychiatry*, *22*(3), 394–412. https://doi.org/10.1002/wps.21120

[4] le Hellard, S., Rietschel, M., & Ressler, K. (2023). Epigenetic markers for treatment response in mental disorders. *European Neuropsychopharmacology*, *75*, S48–S49. https://doi.org/10.1016/j.euroneuro.2023.08.099

[5] Blokhin, I. O., Khorkova, O., Saveanu, R. V., & Wahlestedt, C. (2020). Molecular mechanisms of psychiatric diseases. *Neurobiology of Disease*, *146*, 105136. https://doi.org/10.1016/j.nbd.2020.105136

[6] Papastergiou, J., Quilty, L. C., Li, W., Thiruchselvam, T., Jain, E., Gove, P., …, & Pojskic, N. (2021). Pharmacogenomics guided versus standard antidepressant treatment in a

community pharmacy setting: A randomized controlled trial. *Clinical and Translational Science*, *14*(4), 1359–1368. https://doi.org/10.1111/cts.12986

[7] Dakal, T. C., Xu, C., & Kumar, A. (2025). Advanced computational tools, artificial intelligence and machine-learning approaches in gut microbiota and biomarker identification. *Frontiers in Medical Technology*, *6*, 1434799. https://doi.org/10.3389/fmedt.2024.1434799

[8] Lin, E., Lin, C.-H., & Lane, H.-Y. (2020). Precision psychiatry applications with pharmacogenomics: Artificial intelligence and machine learning approaches. *International Journal of Molecular Sciences*, *21*(3), 969. https://doi.org/10.3390/ijms21030969

[9] Nerella, S., Bandyopadhyay, S., Zhang, J., Contreras, M., Siegel, S., Bumin, A., . . . , & Rashidi, P. (2024). Transformers and large language models in healthcare: A review. *Artificial Intelligence in Medicine*, *154*, 102900. https://doi.org/10.1016/j.artmed.2024.102900

[10] Cruz-Gonzalez, P., He, A. W.-J., Lam, E. P., Ng, I. M. C., Li, M. W., Hou, R., . . . , & Vidaña, D. I. S. (2025). Artificial intelligence in mental health care: A systematic review of diagnosis, monitoring, and intervention applications. *Psychological Medicine*, *55*, e18. https://doi.org/10.1017/S0033291724003295

[11] Dhieb, D., & Bastaki, K. (2025). Pharmaco-multiomics: A new frontier in precision psychiatry. *International Journal of Molecular Sciences*, *26*(3), 1082. https://doi.org/10.3390/ijms26031082

[12] Sathyanarayanan, A., Mueller, T. T., Moni, M. A., Schueler, K., Baune, B. T., Lio, P., . . . , & Xicota, L. (2023). Multi-omics data integration methods and their applications in psychiatric disorders. *European Neuropsychopharmacology*, *69*, 26–46. https://doi.org/10.1016/j.euroneuro.2023.01.001

[13] Acharya, D., & Mukhopadhyay, A. (2024). A comprehensive review of machine learning techniques for multi-omics data integration: Challenges and applications in precision oncology. *Briefings in Functional Genomics*, *23*(5), 549–560. https://doi.org/10.1093/bfgp/elae013

[14] Biswas, A. A. (2024). A comprehensive review of explainable AI for disease diagnosis. *Array*, *22*, 100345. https://doi.org/10.1016/j.array.2024.100345

[15] Sun, J., Dong, Q.-X., Wang, S.-W., Zheng, Y.-B., Liu, X.-X., Lu, T.-S., . . . , & Han, Y. (2023). Artificial intelligence in psychiatry research, diagnosis, and therapy. *Asian Journal of Psychiatry*, *87*, 103705. https://doi.org/10.1016/j.ajp.2023.103705

[16] Kendler, K. S., Ohlsson, H., Sundquist, J., & Sundquist, K. (2021). The patterns of family genetic risk scores for eleven major psychiatric and substance use disorders in a Swedish national sample. *Translational Psychiatry*, *11*(1), 326. https://doi.org/10.1038/s41398-021-01454-z

[17] Vilhjalmsson, B., Zeng, J., & Wray, N. (2023). Advances in polygenic score methods and applications in psychiatric genetics. *European Neuropsychopharmacology*, *75*, S29. https://doi.org/10.1016/j.euroneuro.2023.08.062

[18] Smigielski, L., Jagannath, V., Rössler, W., Walitza, S., & Grünblatt, E. (2020). Epigenetic mechanisms in schizophrenia and other psychotic disorders: A systematic review of empirical human findings. *Molecular Psychiatry*, *25*(8), 1718–1748. https://doi.org/10.1038/s41380-019-0601-3

[19] Antunes, A. S., & Martins-de-Souza, D. (2023). Single-cell RNA sequencing and its applications in the study of psychiatric disorders. *Biological Psychiatry Global Open Science*, *3*(3), 329–339. https://doi.org/10.1016/j.bpsgos.2022.03.013

[20] Rowlett, C. C., & Liu, W. M. (2022). The effects of site specific histone modifications on nucleosomal DNA accessibility. *The FASEB Journal*, *36*(S1). https://doi.org/10.1096/fasebj.2022.36.S1.R1987

[21] Cánepa, E. T., & Berardino, B. G. (2024). Epigenetic mechanisms linking early-life adversities and mental health. *Biochemical Journal*, *481*(10), 615–642. https://doi.org/10.1042/BCJ20230306

[22] Chmielowiec, K., Chmielowiec, J., Masiak, J., Strońska-Pluta, A., Lachowicz, M., Boroń, A., . . . , & Grzywacz, A. (2023). DNA methylation of the dopamine transporter *DAT1* gene—Bliss seekers in the light of epigenetics. *International Journal of Molecular Sciences*, *24*(6), 5265. https://doi.org/10.3390/ijms24065265

[23] Scala, J. J., Ganz, A. B., & Snyder, M. P. (2023). Precision medicine approaches to mental health care. *Physiology*, *38*(2), 82–98. https://doi.org/10.1152/physiol.00013.2022

[24] Liu, J., Li, X., & Luo, X.-J. (2021). Proteome-wide association study provides insights into the genetic component of protein abundance in psychiatric disorders. *Biological Psychiatry*, *90*(11), 781–789. https://doi.org/10.1016/j.biopsych.2021.06.022

[25] Lin, C.-C., & Huang, T.-L. (2020). Brain-derived neurotrophic factor and mental disorders. *Biomedical Journal*, *43*(2), 134–142. https://doi.org/10.1016/j.bj.2020.01.001

[26] Zhang, X., Valeri, J., Eladawi, M. A., Gisabella, B., Garrett, M. R., Vallender, E. J., . . . , & O'Donovan, S. M. (2024). Transcriptomic analysis of the amygdala in subjects with schizophrenia, bipolar disorder and major depressive disorder reveals differentially altered metabolic pathways. *Schizophrenia Bulletin*, sbae193. https://doi.org/10.1093/schbul/sbae193

[27] van Kruining, D., Luo, Q., van Echten-Deckert, G., Mielke, M. M., Bowman, A., Ellis, S., . . . , & Martinez-Martinez, P. (2020). Sphingolipids as prognostic biomarkers of neurodegeneration, neuroinflammation, and psychiatric diseases and their emerging role in lipidomic investigation methods. *Advanced Drug Delivery Reviews*, *159*, 232–244. https://doi.org/10.1016/j.addr.2020.04.009

[28] Ni, J.-J., Xu, Q., Yan, S.-S., Han, B.-X., Zhang, H., Wei, X.-T., . . . , & Zhang, L. (2022). Gut microbiota and psychiatric disorders: A two-sample Mendelian randomization study. *Frontiers in Microbiology*, *12*, 737197. https://doi.org/10.3389/fmicb.2021.737197

[29] Di Minno, A., Gelzo, M., Caterino, M., Costanzo, M., Ruoppolo, M., & Castaldo, G. (2022). Challenges in metabolomics-based tests, biomarkers revealed by metabolomic analysis, and the promise of the application of metabolomics in precision medicine. *International Journal of Molecular Sciences*, *23*(9), 5213. https://doi.org/10.3390/ijms23095213

[30] Wilson, D. R., Binford, L., & Hickson, S. (2024). The gut microbiome and mental health. *Journal of Holistic Nursing*, *42*(1), 79–87. https://doi.org/10.1177/08980101231170487

[31] Cheng, J., Hu, H., Ju, Y., Liu, J., Wang, M., Liu, B., & Zhang, Y. (2024). Gut microbiota-derived short-chain fatty acids and depression: Deep insight into biological mechanisms and potential applications. *General Psychiatry*, *37*(1), e101374. http://dx.doi.org/10.1136/gpsych-2023-101374

[32] Chen, Z. S., Kulkarni, P., Galatzer-Levy, I. R., Bigio, B., Nasca, C., & Zhang, Y. (2022). Modern views of machine learning for precision psychiatry. *Patterns*, *3*(11), 100602. https://doi.org/10.1016/j.patter.2022.100602

[33] Yassin, W., Nakatani, H., Zhu, Y., Kojima, M., Owada, K., Kuwabara, H., ..., & Koike, S. (2020). Machine-learning classification using neuroimaging data in schizophrenia, autism, ultra-high risk and first-episode psychosis. *Translational Psychiatry*, *10*(1), 278. https://doi.org/10.1038/s41398-020-00965-5

[34] Tanaka, M. (2025). From serendipity to precision: Integrating AI, multi-omics, and human-specific models for personalized neuropsychiatric care. *Biomedicines*, *13*(1), 167. https://doi.org/10.3390/biomedicines13010167

[35] Chekroud, A. M., Bondar, J., Delgadillo, J., Doherty, G., Wasil, A., Fokkema, M., ..., & Choi, K. (2021). The promise of machine learning in predicting treatment outcomes in psychiatry. *World Psychiatry*, *20*(2), 154–170. https://doi.org/10.1002/wps.20882

[36] Poirot, M. G., Ruhe, H. G., Mutsaerts, H.-J. M., Maximov, I. I., Groote, I. R., Bjørnerud, A., ..., & Caan, M. W. (2024). Treatment response prediction in major depressive disorder using multimodal MRI and clinical data: Secondary analysis of a randomized clinical trial. *American Journal of Psychiatry*, *181*(3), 223–233. https://doi.org/10.1176/appi.ajp.20230206

[37] Rezaii, N., Wolff, P., & Price, B. H. (2022). Natural language processing in psychiatry: The promises and perils of a transformative approach. *The British Journal of Psychiatry*, *220*(5), 251–253. https://doi.org/10.1192/bjp.2021.188

[38] Irving, J., Patel, R., Oliver, D., Colling, C., Pritchard, M., Broadbent, M., ..., & Fusar-Poli, P. (2021). Using natural language processing on electronic health records to enhance detection and prediction of psychosis risk. *Schizophrenia Bulletin*, *47*(2), 405–414. https://doi.org/10.1093/schbul/sbaa126

[39] Benoit, J., Onyeaka, H., Keshavan, M., & Torous, J. (2020). Systematic review of digital phenotyping and machine learning in psychosis spectrum illnesses. *Harvard Review of Psychiatry*, *28*(5), 296–304. https://doi.org/10.1097/hrp.0000000000000268

[40] Patel, R., Wee, S. N., Ramaswamy, R., Thadani, S., Guruswamy, G., Garg, R., ..., & Kollins, S. (2022). NeuroBlu: A natural language processing (NLP) electronic health record (EHR) data analytic tool to generate real-world evidence in mental healthcare. *European Psychiatry*, *65*(S1), S99–S100. https://doi.org/10.1192/j.eurpsy.2022.286

[41] Straw, I., & Callison-Burch, C. (2020). Artificial Intelligence in mental health and the biases of language based models. *PLoS ONE*, *15*(12), e0240376. https://doi.org/10.1371/journal.pone.0240376

[42] Kerz, E., Zanwar, S., Qiao, Y., & Wiechmann, D. (2023). Toward explainable AI (XAI) for mental health detection based on language behavior. *Frontiers in Psychiatry*, *14*, 1219479. https://doi.org/10.3389/fpsyt.2023.1219479

[43] Tortora, L. (2024). Beyond discrimination: Generative AI applications and ethical challenges in forensic psychiatry. *Frontiers in Psychiatry*, *15*, 1346059. https://doi.org/10.3389/fpsyt.2024.1346059

[44] Mouchabac, S., Adrien, V., Falala-Séchet, C., Bonnot, O., Maatoug, R., Millet, B., ..., & Ferreri, F. (2021). Psychiatric advance directives and artificial intelligence: A conceptual framework for theoretical and ethical principles. *Frontiers in Psychiatry*, *11*, 622506. https://doi.org/10.3389/fpsyt.2020.622506

[45] Roy, B., Yoshino, Y., Allen, L., Prall, K., Schell, G., & Dwivedi, Y. (2020). Exploiting circulating MicroRNAs as biomarkers in psychiatric disorders. *Molecular Diagnosis & Therapy*, *24*(3), 279–298. https://doi.org/10.1007/s40291-020-00464-9

[46] Lee, P. H., Feng, Y.-C. A., & Smoller, J. W. (2021). Pleiotropy and cross-disorder genetics among psychiatric disorders. *Biological Psychiatry*, *89*(1), 20–31. https://doi.org/10.1016/j.biopsych.2020.09.026

[47] Alloghani, M., Al-Jumeily, D., Mustafina, J., Hussain, A., & Aljaaf, A. J. (2020). A systematic review on supervised and unsupervised machine learning algorithms for data science. In *Supervised and Unsupervised Learning for Data Science*, 3–21. https://doi.org/10.1007/978-3-030-22475-2_1

[48] Paliwal, A., Jain, S., Kumar, S., Wal, P., Khandai, M., Khandige, P. S., ..., & Srivastava, S. (2024). Predictive Modelling in pharmacokinetics: From in-silico simulations to personalized medicine. *Expert Opinion on Drug Metabolism & Toxicology*, *20*(4), 181–195. https://doi.org/10.1080/17425255.2024.2330666

[49] Del Casale, A., Sarli, G., Bargagna, P., Polidori, L., Alcibiade, A., Zoppi, T., ..., & Pompili, M. (2023). Machine learning and pharmacogenomics at the time of precision psychiatry. *Current Neuropharmacology*, *21*(12), 2395–2408. https://doi.org/10.2174/1570159x21666230808170123

[50] Alchakee, A., Ahmed, M., Eldohaji, L., Alhaj, H., & Saber-Ayad, M. (2022). Pharmacogenomics in psychiatry practice: The value and the challenges. *International Journal of Molecular Sciences*, *23*(21), 13485. https://doi.org/10.3390/ijms232113485

[51] Gerantia, M. (2024). Artificial intelligence in psychiatry: A new paradigm. *European Psychiatry*, *67*(S1), S205–S205. https://doi.org/10.1192/j.eurpsy.2024.442

[52] Şahin, D., Kambeitz-Ilankovic, L., Wood, S., Dwyer, D., Upthegrove, R., Salokangas, R., ..., & PRONIA Study Group. (2024). Algorithmic fairness in precision psychiatry: Analysis of prediction models in individuals at clinical high risk for psychosis. *The British Journal of Psychiatry*, *224*(2), 55–65. https://doi.org/10.1192/bjp.2023.141

[53] van Dellen, E. (2024). Precision psychiatry: Predicting predictability. *Psychological Medicine*, *54*(8), 1500–1509. https://doi.org/10.1017/s0033291724000370

[54] Liu, G.-D., Li, Y.-C., Zhang, W., & Zhang, L. (2020). A brief review of artificial intelligence applications and algorithms for psychiatric disorders. *Engineering*, *6*(4), 462–467. https://doi.org/10.1016/j.eng.2019.06.008

[55] Pardiñas, A. F., Owen, M. J., & Walters, J. T. (2021). Pharmacogenomics: A road ahead for precision medicine in psychiatry. *Neuron*, *109*(24), 3914–3929. https://doi.org/10.1016/j.neuron.2021.09.011

[56] Kilianova, Z., Stollarova, N., Pivackova, L. B., Krenek, P., Goboova, M., Rihova, Z. J., ..., & Klimas, J. (2024). Biomarkers for the prediction and monitoring of the antipsychotic/antidepressant-induced hepatotoxicity: Study protocol. *Pharmacogenomics*, *25*(16–18), 667–678. https://doi.org/10.1080/14622416.2025.2456449

How to Cite: Adeyemi-Benson, O. S. (2025). Precision Psychiatry: Leveraging Multi-omics and AI for Personalized Mental Health Treatment. *Medinformatics*. https://doi.org/10.47852/bonviewMEDIN52026001