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Research Progress of Wearable Technology in the Diagnosis and Treatment of Mental Disorders (Postprint)

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Abstract

Wearable technology is an emerging technical field that integrates miniaturized electronic devices with everyday wearable items. By integrating technical means such as sensors, microprocessors, and communication modules, it can achieve functions such as monitoring human physiological data, information interaction, and environmental perception. In recent years, with continuous technological progress, the application of wearable technology in the field of mental disorders has gradually gained attention and demonstrated great potential. Unlike previous studies that mostly focused on the application of wearable technology for a single mental illness or a single function, this paper comprehensively and systematically reviews the applications of wearable technology in the diagnosis, symptom assessment, and treatment of mental disorders, and deeply analyzes its potential advantages and challenges. Furthermore, this paper not only covers mainstream applications but also prospectively points out innovative paths in continuous monitoring of multi-dimensional physiological and behavioral indicators, construction of digital phenotypes, and multi-modal interventions. This aims to provide new ideas for the early identification and precision intervention of mental disorders, and to offer references and insights for clinical diagnosis and treatment practices as well as future research.

Full Text

Preamble

Research Progress of Wearable Technology in the Diagnosis and Treatment of Mental Disorders

Abstract

Mental disorders represent a significant global public health challenge, characterized by high prevalence, high disability rates, and a heavy socioeconomic burden. Traditional clinical assessments rely heavily on subjective self-reports and periodic clinical observations, which often lack the continuity and objectivity required for precise management. In recent years, the rapid development of wearable technology has provided a transformative approach to the objective monitoring and intervention of mental health conditions. By integrating various physiological sensors (such as heart rate variability, electrodermal activity, and sleep patterns) and behavioral tracking (such as physical activity and speech patterns), wearable devices enable the continuous, real-time collection of longitudinal data in naturalistic settings. This paper reviews the current research progress of wearable technology in the screening, diagnosis, monitoring, and therapeutic intervention of major mental disorders, including depression, anxiety disorders, bipolar disorder, and schizophrenia. Furthermore, we discuss the existing challenges—such as data privacy, technical standardization, and clinical validation—and provide perspectives on future development trends in the field of digital psychiatry.

1. Introduction

Mental disorders are complex conditions that affect hundreds of millions of people worldwide. Unlike many physical illnesses that can be diagnosed through clear biological markers, the diagnosis and management of mental disorders have traditionally relied on clinical interviews and standardized scales, such as the PHQ-9 for depression or the GAD-7 for anxiety. While these tools are essential, they are susceptible to recall bias and provide only a “snapshot” of a patient’s state during a clinical visit.

Wearable technology, encompassing smartwatches, fitness trackers, and specialized medical-grade sensors, offers a solution to these limitations. These devices can capture “digital phenotypes” —objective, quantifiable behavioral and physiological data—that reflect an individual’s mental state in their daily life. The integration of machine learning algorithms with this high-dimensional data allows for the identification of subtle patterns that may precede clinical relapse or indicate treatment response.

2. Application of Wearable Technology in Specific Mental Disorders

2.1 Depression and Anxiety Disorders Depression and anxiety are the most common mental health conditions globally. Research has demonstrated that physiological indicators such as Heart Rate Variability (HRV) and Electrodermal Activity (EDA) are closely linked to autonomic nervous system dysregulation in these patients. Wearable devices can monitor these parameters alongside sleep quality and physical activity levels. Studies using machine learning models have shown that combined data from accelerometers and heart rate

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Abstract

Wearable technology is an emerging field that integrates miniaturized electronic devices into everyday wearable items. By incorporating sensors, microprocessors, and communication modules, these technologies enable the monitoring of human physiological data, information interaction, and environmental perception. In recent years, continuous technological advancements have drawn increasing attention to the application of wearable technology in the field of mental disorders, revealing its significant potential. Unlike previous studies that often focused on the application of wearable technology for a single mental illness or a specific function, this paper systematically reviews its comprehensive application in the diagnosis, symptom assessment, and treatment of mental disorders. Furthermore, it provides an in-depth analysis of the potential advantages and challenges associated with these technologies. Beyond mainstream applications, this review prospectively identifies innovative pathways, such as the continuous monitoring of multi-dimensional physiological and behavioral indicators, the construction of digital phenotypes, and multimodal interventions. The objective is to provide new perspectives for the early identification and precision intervention of mental disorders, serving as a reference and inspiration for clinical practice and future research.

Keywords: Wearable electronic devices; Mental disorders; Diagnosis; Symptom assessment; Treatment; Review

Introduction

Wearable technology represents a transformative approach to healthcare by bridging the gap between clinical environments and the daily lives of patients. In the realm of psychiatry, where diagnosis and monitoring have traditionally relied on subjective self-reports and periodic clinical interviews, the introduction of objective, continuous data collection offers a paradigm shift.

1. Applications in Diagnosis and Symptom Assessment

The integration of sensors into wearable devices allows for the real-time tracking of various physiological markers, including heart rate variability (HRV), electrodermal activity (EDA), sleep patterns, and physical activity levels. These metrics serve as critical indicators of a patient's psychological state. For instance, changes in sleep architecture or circadian rhythms often precede the onset of depressive or manic episodes. By leveraging machine learning algorithms to analyze these data streams, clinicians can identify subtle patterns that may be invisible during a standard clinical consultation.

Furthermore, wearable technology facilitates the development of “digital phenotypes” —a comprehensive digital footprint of an individual's behavior and physiology. This multi-dimensional approach enables a more nuanced understanding of mental disorders, moving beyond categorical diagnoses toward a more personalized, dimensional assessment of mental health.

2. Applications in Treatment and Intervention

Beyond diagnosis, wearable devices are increasingly utilized in the treatment of mental disorders. These applications range from biofeedback mechanisms that help patients manage anxiety in real-time to sophisticated closed-loop systems that adjust therapeutic interventions based on physiological feedback.

Multimodal interventions, which combine wearable data with mobile health (mHealth) platforms, allow for “just-in-time” adaptive interventions (JITAIs). For example, if a wearable device detects physiological signs of escalating stress, a connected smartphone application can prompt the user to engage in a mindfulness exercise or contact a healthcare provider, thereby preventing a full-blown crisis.

3. Advantages and Challenges

The primary advantage of wearable technology lies in its ability to provide objective, longitudinal data in a non-invasive manner. This reduces the recall bias inherent in traditional assessment methods and allows for the monitoring of treatment efficacy over time.

However, several challenges remain. Data privacy and security are paramount, as the sensitive nature of mental health data requires robust protection. Additionally, there is a need for standardized protocols for data collection and

analysis to ensure clinical validity. The “noise” inherent in real-world data—such as motion artifacts in physiological signals—also poses a significant technical hurdle for researchers and developers.

4. Future Perspectives

The future of wearable technology in mental health lies in the refinement of multi-dimensional monitoring and the integration of artificial intelligence to provide predictive analytics. By identifying early warning signs of relapse through digital phenotyping, the healthcare system can shift from a reactive to a proactive model of care. This transition toward precision psychiatry promises to improve patient outcomes and reduce the global burden of mental disorders.

In conclusion, while wearable technology is still an evolving field, its integration into the diagnosis and treatment of mental disorders offers a promising frontier for clinical innovation. Continued interdisciplinary research is essential to overcome current limitations and fully realize the potential of these technologies in improving mental health care.

Abstract

Wearable technology is an emerging technology field that combines miniaturized electronic devices with daily wearable items. Through the integration of sensors, microprocessors, and communication modules, it enables the monitoring of human physiological data, information interaction, and environmental sensing. In recent years, with continuous technological progress, the application of wearable technology in the field of mental disorders has gradually attracted attention and shown great potential. Unlike previous studies that primarily focused on the application of wearable technology for a single mental disorder or a single function, this paper comprehensively and systematically reviews the use of wearable technology in the diagnosis, symptom assessment, and treatment of mental disorders, while also conducting an in-depth analysis of its potential advantages and challenges. Furthermore, this paper not only covers mainstream applications but also prospectively highlights innovative pathways in continuous monitoring of multidimensional physiological and behavioral indicators, constructing digital phenotypes, and implementing multimodal interventions. It aims to provide new insights for the early identification and precise intervention of mental disorders, offering references and inspiration for clinical practice and future research.

Key words: Wearable electronic devices; Mental disorders; Diagnosis; Symptom assessment; Therapy; Review

Mental disorders are a class of diseases characterized by impairments in cognition, emotion, volition, and behavior. Common types include schizophrenia, bipolar disorder, depressive disorders, and anxiety disorders. According to the World Mental Health Survey, the lifetime prevalence of mental disorders is 28.6% for men and 29.8% for women. FENG Y C, LIU L W, XUE J Y, et al. Research

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Mental disorders not only severely impact the physical and mental health of patients but also impose a heavy burden on families and society. However, due to the diversity of symptoms, the high subjectivity of clinical assessments, and insufficient public awareness, these disorders are often overlooked or misunderstood, resulting in many patients failing to receive timely and effective diagnosis and treatment. In recent years, wearable technology has emerged as a promising tool in the diagnosis and treatment of mental disorders, offering continuous real-time monitoring and portability. These devices can quantitatively, objectively, and accurately measure an individual's physiological and behavioral characteristics. This article aims to review the current application status of wearable technology in the diagnosis, assessment, and treatment of mental disorders, while discussing the advantages and limitations of its application in this field, with the goal of providing a theoretical basis and practical guidance for clinicians and technical personnel.

1 Overview of Wearable Technology

The concept of wearable technology was first proposed by the MIT Media Lab in the 1960s. Its core principle lies in the deep integration of electronic technology, sensor technology, and wireless communication with everyday wearable items to achieve functions such as health monitoring, real-time information interaction, and environmental perception. Compared to traditional detection methods, wearable devices overcome the technical limitation of “collection followed by detection” by integrating sample collection and analysis into a single process, thereby significantly improving monitoring efficiency. With continuous advancements in electronics and sensor technologies, wearable devices have evolved from early single-function forms into intelligent systems with diverse capabilities. Today, this technology demonstrates significant application value and developmental potential across fields including healthcare, sports science, environmental monitoring, military, and industry. In recent years, the application of wearable technology in the field of mental health has attracted widespread attention from researchers. A substantial body of research indicates that this technology offers unique advantages in the early diagnosis, dynamic assessment, and interventional treatment of mental disorders. Regarding diagnosis and assessment, technologies such as smart bracelets, sensor patches, and portable electroencephalogram (EEG) devices have become relatively mature. These devices can collect patients' physiological and behavioral data (such as heart rate variability, galvanic skin response, and movement patterns) in real-time and continuously, providing an objective and quantitative basis for clinical symptom assessment. Examples include smartwatches and bracelets for real-time monitoring of heart rate, heart rate variability, electrodermal activity, physical

activity, and sleep parameters, as well as wearable transcranial magnetic stimulation devices. Note: Fitbit is a type of smart fitness tracker; AS refers to automated ingestion monitoring systems.

These technologies provide a reliable basis for clinical practice. In terms of therapeutic intervention, the development of products such as wearable transcranial magnetic stimulation (TMS) devices and smart glasses has introduced new possibilities for the treatment of mental disorders (Table 1) [?].

2 Application of Wearable Technology in Auxiliary Diagnosis of Mental Disorders

Currently, the clinical diagnostic framework for mental disorders relies primarily on traditional methods such as clinical symptom observation, medical history collection, standardized scale assessments, and mental status examinations. However, these traditional approaches face numerous limitations, including high subjectivity, poor reproducibility, time-consuming clinical interviews, and a shortage of specialized personnel, which frequently lead to the underdiagnosis of mental disorders.

Against this backdrop, developing objective, quantifiable, and clinically practical auxiliary diagnostic technologies is of significant practical importance. In recent years, the advancement of wearable technology has provided new possibilities for the early identification and diagnosis of mental disorders. By continuously monitoring multi-dimensional physiological and behavioral indicators—such as heart rate variability (HRV), electrodermal activity (EDA), and movement patterns—and integrating these with advanced machine learning algorithms, wearable devices can construct “digital phenotypes” of mental disorders. This technological paradigm not only achieves the objective quantification of disease characteristics but, more importantly, provides a novel research methodology for the early identification and subclinical state monitoring of mental disorders.

Schizophrenia

Schizophrenia is a highly heterogeneous neurodevelopmental disorder. Its core pathological features encompass multiple dimensions, including positive symptoms (such as hallucinations and delusions), negative symptoms (such as affective flattening), and cognitive impairment.

Traditional diagnostic methods based on clinical symptomatology face significant challenges in early disease identification and subtype differentiation. The emergence of wearable technology provides a new technical pathway to overcome these diagnostic dilemmas. For example, a wearable wireless ECG monitoring system developed by INOUE can measure autonomic nervous system response characteristics induced by yoga. When combined with a Linear Discriminant Analysis (LDA) algorithm, this system achieves accurate differentiation between patients with schizophrenia and healthy controls, reaching a sensitivity of 91%

and a specificity of 82%.

Table 1: Types of Wearable Technology and Their Clinical Applications

| Wearable Technology Type | Clinical Application Scope | Representative Research |
|--|---|---|
| Physiological Sensors (e.g., Heart rate, sleep, activity) | (1) Daily monitoring of patients with mental disorders; (2) Auxiliary diagnosis and efficacy evaluation; (3) Early warning of symptom fluctuations. | LIPSCHITZ et al.: Aided bipolar disorder diagnosis using heart rate, sleep, and activity data collected via Fitbit. |
| Portable EEG Devices (Continuous EEG signal acquisition) | (1) Neurological function assessment; (2) Neurofeedback therapy; (3) Monitoring of brain functional states. | AS et al.: Demonstrated that EEG-based neurofeedback training significantly improves symptoms of Post-Traumatic Stress Disorder (PTSD). |
| Light Therapy Glasses (Regulating melatonin via specific wavelengths) | (1) Circadian rhythm regulation; (2) Improvement of depressive symptoms; (3) Intervention for sleep disorders. | DU BOIS et al.: Confirmed the definitive efficacy of light therapy glasses for postpartum depression. |
| Wearable rTMS (Generating pulsed magnetic fields to regulate cortical excitability) | (1) Treatment of depressive disorders; (2) Neuromodulation therapy; (3) Brain function rehabilitation. | SWANSON et al.: Developed a wearable repetitive Transcranial Magnetic Stimulation (rTMS) device enabling home-based treatment for depression. |
| Smart Glasses (Real-time facial expression recognition and social cues) | (1) Social skills training; (2) Emotion recognition assistance; (3) Intervention for Autism Spectrum Disorder (ASD). | Superpower Glass Project: Significantly improved the social abilities of patients with Autism Spectrum Disorder. |

| Wearable Technology Type | Clinical Application Scope | Representative Research |
|---|--|---|
| Wearable Cameras (Recording daily events) | (1) Memory function training; (2) Cognitive rehabilitation; (3) Reality orientation therapy. | DASSING et al.: Improved autobiographical memory impairment in schizophrenia patients through scene reconstruction. |

The system achieved an accuracy of 81%. This system not only provides an objective diagnostic reference but also quantitatively assesses illness severity through standardized Z-scores and visual mapping, offering an innovative solution for the early screening and home monitoring of schizophrenia. However, the study has certain limitations: it lacks external validation, and the participant pool was restricted to schizophrenia patients and healthy volunteers, without comparing schizophrenia patients against those with other mental disorders.

In contrast, the research by NGUYEN et al. demonstrated high efficacy in distinguishing schizophrenia from mood disorders (including bipolar and unipolar disorders) by utilizing deep learning models and wearable device data, achieving an accuracy of 88%. Notably, COTES et al. proposed an innovative theoretical framework that integrates multimodal wearable data—such as motor activity, speech features, facial expressions, and eye gaze—to achieve differential diagnosis across various clinical subtypes of schizophrenia; however, this concept has not yet undergone clinical translation.

Making substantive progress in this direction, the study by DE BOER et al. successfully differentiated between schizophrenia patients with predominantly positive symptoms and those with predominantly negative symptoms by analyzing speech parameters, including pause duration, frequency, spectrum, and amplitude characteristics.

In the future, further research is required to validate the reliability and effectiveness of multimodal wearable data integration and analysis in the diagnosis of schizophrenia.

Bipolar Disorder

Bipolar disorder is clinically characterized by alternating episodes of mania or hypomania and depression, transitions that are often accompanied by significant physiological and behavioral changes. Wearable technology provides a novel methodology for state identification and research in bipolar disorder by continuously monitoring multiple physiological indicators. For instance, Anmella et al. utilized the Empatica E4 wristband to record the electrodermal activity (EDA) of patients with bipolar disorder. Their findings revealed that

EDA was significantly lower during depressive episodes; however, there was no statistically significant difference in EDA between patients in manic episodes and the control group. This discovery suggests that EDA may serve as a potential objective biomarker for mood state transitions.

Furthermore, Lipschitz et al. collected heart rate, sleep, and activity data using Fitbit devices to construct personalized machine learning models. These models achieved accurate prediction of mood symptoms in bipolar patients, yielding an area under the curve (AUC) greater than 85%. To ensure the stability and reliability of the models, the researchers partitioned the dataset chronologically into training and testing sets, employing time-series split cross-validation and comparing multiple algorithms (Table 2). Nevertheless, the lack of external validation limits the generalizability of these findings to some extent.

In another approach, Faurholt-Jepsen analyzed smartphone communication and usage data combined with machine learning models to classify unipolar and bipolar disorders. While the models showed promise, they performed poorly when using leave-one-out cross-validation, indicating that their practical discriminative efficacy requires further verification. Consequently, due to the significant heterogeneity in physiological responses between individuals, the diagnostic performance of current wearable technology for bipolar disorder must be further validated through large-sample studies.

Depressive disorder is a psychiatric condition primarily characterized by low mood, anhedonia, and diminished volition. It is frequently accompanied by characteristic physiological and behavioral alterations, such as circadian rhythm disturbances and reduced physical activity. Wearable devices provide objective data support for the auxiliary diagnosis of depressive disorder by continuously monitoring physiological and behavioral indicators, including heart rate variability (HRV), electrodermal activity (EDA), physical activity levels, and sleep patterns.

Recent research demonstrates that by collecting pulse wave, EDA, and acceleration data from the daily activities of patients with depressive disorder and healthy controls, researchers can extract static and dynamic features to achieve a 76% recognition accuracy within five minutes using machine learning models. Furthermore, with longer data collection periods, this accuracy can reach 90%. Another study utilized wearable devices to collect resting-state electroencephalogram (EEG) data, which, when analyzed with an improved graph convolutional neural network model, achieved a recognition accuracy of 96.5% for depressive disorder. These findings suggest that the integration of wearable devices with machine learning models can effectively assist in the diagnosis of depressive disorder, offering new possibilities for rapid screening and routine monitoring.

Anxiety disorders are a class of psychiatric conditions characterized by excessive and persistent fear, anxiety, and associated autonomic nervous system dysfunction. These disorders also manifest through specific physiological and behavioral changes. Similar to their application in depressive disorders, wearable devices

can assist in the identification of anxiety disorders by providing real-time monitoring of these characteristic indicators. For instance, increased heart rate, enhanced electrodermal activity (EDA), and irregular respiration rates may all serve as potential signals of anxiety. Furthermore, research by Cheng et al. has demonstrated that the resting-state heart rate variability (HRV) of patients with anxiety disorders is significantly lower than that of healthy individuals.

Tomasi et al. further confirmed that Heart Rate Variability (HRV) can serve as a potential biomarker for anxiety disorders, demonstrating that it can be measured non-invasively using electrocardiography (ECG) or photoplethysmography (PPG) technology. In addition to physiological changes, patients with anxiety disorders often exhibit altered behavioral patterns, such as reduced physical activity and abnormal sleep architecture. Cox et al. found that these patients experience increased subjective sleep disturbances, shortened total sleep time, and decreased sleep continuity; consequently, these indicators can be effectively utilized for the identification of anxiety symptoms.

Another large-scale study based on the Adolescent Brain Cognitive Development (ABCD) project ($N = 11,878$) integrated multimodal data—including wearable device monitoring data, genomic information, and clinical diagnoses—to construct a diagnostic model using machine learning algorithms. Notably, the study found that dynamic behavioral features (including sleep quality, sleep stage transitions, energy expenditure, and gait characteristics) possessed higher discriminatory power than static features. This finding provides a critical foundation for developing objective recognition systems for anxiety disorders based on wearable technology.

Furthermore, the research revealed significant differences in heart rate dynamic characteristics between patients with attention deficit hyperactivity disorder (ADHD) and those with anxiety disorders. Specifically, the heart rate dynamics of ADHD patients were most pronounced during the afternoon, whereas patients with anxiety disorders exhibited more distinctive features in sleep-related dynamics during the night. These physiological differences facilitate the use of wearable device data to differentiate between individuals with different conditions, thereby enhancing diagnostic precision.

The developed digital phenotypic models have significantly improved diagnostic accuracy. Beyond the aforementioned mental disorders, wearable technology has also demonstrated promising applications in the auxiliary diagnosis of other psychiatric conditions. For instance, in research concerning obsessive-compulsive disorder (OCD), NFELDT et al. [?] utilized wrist-worn biosensors to continuously monitor patients' physiological signals, including heart rate, skin temperature, electrodermal activity (EDA), and blood volume pulse.

Chinese General Practice has established a predictive model for OCD episodes. In the field of neurodevelopmental disorders, wearable devices utilize high-precision inertial measurement units to quantitatively evaluate children's motor characteristics, including movement complexity, the radius of curvature

of movement trajectories, and the frequency of repetitive behaviors. These parameters can be employed to assist in the diagnosis of autism spectrum disorder (ASD). GONZALEZ et al. proposed that high-accuracy diagnosis of ADHD can be achieved by measuring children's activity levels and movement patterns combined with machine learning algorithms. Furthermore, wearable technology has been investigated for its potential in the auxiliary diagnosis of conditions such as post-traumatic stress disorder (PTSD) and panic attacks.

However, current research in this area is largely in the exploratory stage with small sample sizes, which presents certain limitations. On one hand, due to limited sample sizes and a lack of validation through multicenter randomized controlled trials, most studies remain focused on the preliminary exploration of model performance. These studies prioritize the improvement and optimization of internal research and have not yet conducted external validation. Consequently, the generalizability of these models remains unclear, and the universality of the research results is restricted. On the other hand, most studies only compare patients with healthy control groups, resulting in insufficient efficacy in distinguishing between different psychiatric disorders. This makes it difficult to meet the demands of precise clinical diagnosis.

Therefore, to apply the research findings of wearable technology in the auxiliary diagnosis of mental disorders to clinical practice, it is necessary to further expand sample sizes, enhance the ability of models to differentiate between various psychiatric conditions, and conduct rigorous external validation. It is also necessary to integrate clinical assessment methods to enhance the accuracy and reliability of the diagnosis.

3 Application of Wearable Technology in Symptom Assessment of Mental Disorders

In addition to assisting in the diagnosis of mental disorders, wearable technology can be applied to the assessment of clinical symptoms, primarily covering the following key symptom dimensions: emotional symptoms, behavioral patterns, sleep abnormalities, and the risk of self-harm or suicide.

Emotional State Assessment Wearable technology provides robust support for the monitoring and evaluation of emotional states in patients with mental disorders by real-time tracking of physiological data such as heart rate, heart rate variability (HRV), electrodermal activity (EDA), and respiration rate. For example, a multimodal monitoring system developed by Patlar et al. [?], which encompasses various biological signals including electrocardiogram (ECG), EDA, body temperature, and blood oxygen saturation, can effectively identify anxiety or depressive emotional states in patients.

Transformer models constructed based on wearable physiological data have also demonstrated that physiological signals such as heart rate, skin conductance, and acceleration can effectively identify an individual's emotional state in daily life. Beyond physiological data, wearable devices can incorporate voice and

facial expression analysis to further enhance the accuracy of emotional state assessment. For instance, a self-powered polyvinyl alcohol-gellan gum-glycerol thermoelectric gel patch can perceive the activity of 11 facial muscles in real-time and utilize machine learning algorithms for expression and emotion recognition. Consequently, in clinical practice, this real-time and continuous emotional monitoring helps physicians more accurately assess changes in a patient's condition and formulate personalized treatment plans. For example, by monitoring emotional responses in different contexts, doctors can better understand a patient's triggers, thereby designing targeted psychological interventions.

Behavioral Pattern Monitoring and Analysis In the clinical assessment of mental disorders, objective monitoring of behavioral symptoms is crucial for understanding a patient's overall condition and formulating treatment plans. Wearable devices provide detailed information regarding individual behavioral patterns by monitoring daily activity data—such as step counts, activity intensity, and movement patterns—thereby offering an important basis for assessing behavioral symptoms in patients with mental disorders. For example, Tchuente et al. [?] utilized the built-in accelerometers and gyroscopes of smartwatches, combined with a hybrid model integrating the k -nearest neighbors (kNN) and ReliefF algorithms, to achieve precise differentiation between aggressive behaviors (e.g., punching, pushing) and non-aggressive behaviors (e.g., clapping, waving). The recognition accuracy exceeded 98%, validating the high reliability of wearable devices in identifying aggressive behavior. Furthermore, Rad et al. [?] employed multimodal wearable technology (including electrophysiological activity sensors, skin temperature sensors, and accelerometers) to synchronously monitor emotional stress responses, autonomic nervous system status, and movement characteristics. Combined with machine learning algorithms, they successfully achieved automated recognition of challenging behaviors in patients with autism spectrum disorder, providing technical support for the implementation of precision behavioral interventions in clinical settings. In clinical practice, this detection and analysis of behavioral patterns are of great significance. For instance, by monitoring activity intensity and movement patterns, physicians can evaluate whether a patient's activity level is consistent with their clinical status and adjust treatment plans accordingly. Additionally, such monitoring helps physicians assess treatment efficacy and provide patients with more accurate rehabilitation guidance.

Sleep Abnormality Monitoring Sleep abnormality is a common symptom among patients with mental disorders, and its monitoring is of great significance for diagnosis, treatment, and rehabilitation. Wearable devices, such as smartwatches and fitness trackers, leverage built-in sensors (e.g., accelerometers, heart rate sensors, and respiratory sensors) to monitor various parameters during sleep in a real-time and non-invasive manner. These parameters include total sleep time, sleep onset and wake times, sleep stage distribution, heart rate fluctuations, and respiration. For example, Di Credico et al. [?] used photoplethysmography (PPG) sensors to measure HRV and combined this with infrared thermal imaging to measure facial skin temperature, establishing a high-sensitivity sleep

quality assessment model that provides a new method for the early identification of sleep abnormalities in mental disorders. Furthermore, Lim et al. [?] utilized Fitbit wearable devices to conduct long-term sleep-wake cycle monitoring in 168 patients with mood disorders, effectively assessing sleep abnormalities. By combining these data with the XGBoost algorithm, the researchers successfully predicted depressive, manic, and hypomanic episodes. These studies indicate that wearable technology can not only accurately assess sleep quality but also support the diagnosis and intervention of mood disorders by monitoring features such as sleep and circadian rhythms.

Clinically, objectively recording sleep architecture parameters (such as the proportion of slow-wave sleep and rapid eye movement sleep latency) can provide a quantitative basis for the differential diagnosis of mental disorders. Secondly, long-term dynamic monitoring can establish objective evaluation indicators for treatment responsiveness; observing improvement trends, such as increased sleep efficiency and reduced nocturnal awakenings, often signals the alleviation of clinical symptoms, which provides critical guidance for adjusting treatment regimens.

Suicide and Self-Harm Risk Assessment Suicidal and self-harming behaviors are among the most serious symptoms in patients with mental disorders. Their early identification and precise intervention are of great clinical significance for reducing mortality rates.

In recent years, objective monitoring systems based on multimodal wearable technology, combined with machine learning analysis, have provided innovative solutions for the dynamic assessment of suicide and self-harm risks. For example, research has found that short sleep duration and decreased subjective sleep quality can predict an increase in suicidal ideation the following day; this finding provides a theoretical basis for assessing suicide risk by monitoring sleep disturbances via wearable devices. Zhu et al. [?] employed smart wristbands combined with ecological momentary assessment (EMA) technology to conduct a 28-day longitudinal study of 75 adolescents with mental disorders. The results showed that objective data collected via wearables could not only effectively identify dynamic fluctuations in suicide risk but also compensate for recall bias inherent in traditional subjective reports, significantly enhancing assessment reliability and clinical utility. Furthermore, Cantin-Garside et al. [?] innovatively applied acceleration sensors to collect movement data, constructing a self-harm behavior recognition model using Support Vector Machine (SVM) algorithms that achieved an accuracy of 99.1%. This breakthrough provides a technical paradigm for the automated monitoring of self-harm behaviors. In summary, wearable technology combined with machine learning models offers new perspectives and methods for the assessment of suicide and self-harm risks. Future research should further optimize monitoring technologies and algorithmic models to improve assessment accuracy and reliability, providing stronger support for the risk assessment and intervention of suicide and self-harm in patients with mental disorders.

In conclusion, in the clinical symptom assessment of mental disorders, behavioral characterization serves as an important basis for identification and diagnosis, and the multidimensional data collected by wearable devices provide a new pathway for the quantitative analysis of these characterizations. These data include physiological parameters reflecting the autonomic nervous system, such as heart rate, HRV, and EDA, as well as behavioral data such as movement, sleep, voice, facial expressions, and social interactions. Together, these data provide robust support for the identification and dynamic monitoring of mental disorders. However, it is important to note that fluctuations in these indicators may be influenced by multiple factors, including physiological factors, environmental factors, individual baseline differences, and measurement errors; thus, a single data source is often insufficient for accurate judgment. Therefore, to achieve a more scientific and precise assessment of mental disorders, it is essential to integrate multimodal data and combine them with professional methods such as clinical history taking and scale-based assessments to construct a comprehensive evaluation system.

4 Application of Wearable Technology in the Treatment of Mental Disorders

Wearable technology offers new possibilities for the treatment of mental disorders. It not only provides real-time data support for clinical interventions and enhances therapeutic efficacy through personalized treatment but can also serve directly as a therapeutic device, offering patients innovative treatment solutions.

Schizophrenia

The treatment of schizophrenia relies primarily on pharmacological intervention; however, some patients exhibit poor adherence, finding it difficult to maintain a regular medication regimen, which subsequently leads to disease relapse. To address this issue, wearable technology has significantly improved treatment adherence through real-time monitoring and reminders. For example, research has led to the development of integrated systems for depressive disorders, anxiety disorders, schizophrenia, and ADHD.

Clinical Applications and Diagnostic Categories

The application of these technologies spans several critical psychiatric domains: 1. Depressive disorders and bipolar disorder (depressive episodes). 2. ADHD and bipolar disorder (manic episodes). 3. Anxiety disorders and Post-Traumatic Stress Disorder (PTSD). 4. Schizophrenia, often in comorbidity with depressive disorders or ADHD. 5. Autism Spectrum Disorder (ASD) and Social Anxiety Disorder.

Association of Wearable Device Indicators with Behavioral Representations of Mental Disorders

Wearable devices provide objective physiological metrics that serve as proxies for the behavioral representations of various mental disorders. The following indicators are particularly salient:

Heart Rate Metrics and Emotional Regulation

1. **Sustained Elevation of Resting Heart Rate:** This indicator suggests increased sympathetic nervous system excitability, which is closely related to stress responses or emotional fluctuations. It may reflect a state of chronic stress and a diminished capacity for emotional regulation in the patient.
2. **Increased Heart Rate Variability (HRV) Fluctuations:** This often manifests as emotional instability.
3. **Decreased HRV:** A reduction in HRV indicates autonomic nervous system dysfunction. Behaviorally, this manifests as weakened emotional regulation and decreased behavioral adaptability when the individual is subjected to stressful environments.

These physiological markers provide a continuous data stream that allows clinicians to monitor the behavioral states of patients with schizophrenia, bipolar disorder, and anxiety disorders more accurately than traditional self-reporting methods.

Abnormalities in these indicators may be associated with various psychiatric disorders, particularly among patients exhibiting deficits in emotional regulation and stress response.

Electrodermal Activity (EDA)

- **Diminished EDA:** This suggests a weakened autonomic nervous system response to stimuli, manifesting as dullness or apathy toward environmental triggers. It may reflect clinical apathy or a profound lack of interest in external stimuli.
- **Enhanced EDA:** This indicates over-activation of the autonomic nervous system, suggesting that the individual may be in a state of hypervigilance.

Movement-Related Data

- **Decreased Activity:** A sustained reduction in step count and movement frequency, coupled with increased sedentary time, suggests anhedonia and a lack of motivation. This may reflect the patient's insufficient drive or diminished interest in activities.
- **Increased Activity:** A sustained increase in step count and movement frequency, manifesting as an inability to sit still and excessive energy. This may indicate that the patient is in a manic or hyperexcitable state.
- **Disrupted Activity Rhythms:** A lack of regularity in daily activities is often closely associated with hypervigilance or avoidant behaviors.

Sleep-Related Data

- **Poor Sleep Quality:** Characterized by prolonged sleep latency, shallow sleep, frequent nocturnal awakenings, and short total sleep duration. This manifests as daytime fatigue, drowsiness, and low productivity, potentially reflecting circadian rhythm disruption or difficulty maintaining sleep.
- **Circadian Rhythm Disruption:** Significant fluctuations in wake-up and sleep times, disordered sleep cycles, or even day-night reversal. These patterns may be related to biological clock misalignment or emotional regulation disorders.

Speech and Language Indicators

- **Reduced Vocal Intensity and Disorganized Expression:** These signs suggest cognitive fragmentation and difficulty in expression, potentially reflecting thought organization disorders or a decline in verbal communication skills.
- **Slowed Speech Rate, Monotonous Intonation, and Poverty of Speech:** These features are often indicative of affective flattening or apathy.
- **Frequent Pauses and Interruptions:** These may result from thought blocking or distractibility, leading to fragmented speech.

Facial Expression Data

- **Diminished Facial Expression:** Reduced facial muscle activity and a lack of expressive diversity suggest affective flattening or blunting. This may reflect a limited capacity for emotional expression.
- **Incongruent Affect:** Facial expressions that do not align with internal emotional states suggest parathymia, which may be related to emotional regulation disorders or cognitive dysfunction.

Social Interaction Data

- **Reduced Eye Contact:** Frequent gaze aversion or avoidance of eye contact during social interactions suggests social avoidance behavior. This may reflect social anxiety or a lack of interest in social engagement.
- **Decreased Frequency of Calls and Messaging:** This indicates social withdrawal and avoidance, potentially reflecting social isolation or a lack of motivation for interpersonal interaction.
- **High Volatility in Communication Frequency:** Large fluctuations in the frequency of calls and messages suggest emotional or social instability, potentially linked to mood swings or social functional impairment.

Note: PTSD = Post-Traumatic Stress Disorder; ADHD = Attention-Deficit/Hyperactivity Disorder; HRV = Heart Rate Variability; EDA = Electrodermal Activity; ASD = Autism Spectrum Disorder.

The Abilify MyCite System (AS) is an intelligent medication monitoring system consisting of aripiprazole tablets embedded with ingestible event marker sensors, a wearable sensor patch, and a smartphone application. This system enables real-time monitoring and recording of medication-taking behavior through sensor signal transmission, which has been shown to significantly improve patient medication adherence .

Further research has conducted in-depth analyses on how the frequency of dashboard usage within the AS affects clinical decision-making and patient outcomes. Findings indicate that physicians who frequently utilize the dashboard can more promptly and accurately track patient adherence, thereby optimizing treatment decisions. Comparative analyses of clinical assessment changes across different dashboard usage frequencies reveal that patients managed by high-frequency users show more significant symptom improvement and better overall prognoses. By providing adherence counseling or education, these physicians are able to adjust treatment plans in a timely manner and implement targeted interventions, which significantly improves long-term patient outcomes. Collectively, these studies demonstrate that wearable technology holds substantial value in supporting treatment decisions and prognostic evaluations for patients with schizophrenia.

In addition to assisting with pharmacological treatments, wearable technology can serve as an integral component of digital therapeutics. By providing real-time monitoring, feedback, and behavioral interventions, these technologies aim to improve the symptoms and functional outcomes of patients with schizophrenia. For instance, cognitive impairment is a core feature of schizophrenia, with deficits in autobiographical memory being particularly prominent. Such memory impairments severely impact a patient's self-awareness and their ability to function in daily life.

Dassing et al. [?] utilized wearable cameras to record the daily activities of patients and implemented a cognitive intervention protocol combining visual review with event cueing. Their findings indicated that this intervention significantly enhanced patients' ability to recall details of recent events, bringing their memory function close to normal levels . Furthermore, wearable devices enable clinicians to conduct comprehensive clinical assessments by monitoring physiological indicators, behavioral patterns, and social interactions.

Specifically, wearable devices can monitor physiological metrics such as heart rate, sleep patterns, and physical activity in real time. These data assist physicians in the timely detection of abnormal states in patients with schizophrenia, allowing for prompt adjustments to treatment plans. This comprehensive approach to monitoring and intervention not only improves patient treatment adherence but also enhances symptoms and functioning through cognitive interventions and real-time tracking. Consequently, these technologies offer novel perspectives and methodologies for the clinical management of schizophrenia.

Bipolar Disorder

In recent years, wearable technology has provided novel support for the treatment of bipolar disorder. These wearable devices can monitor the physiological and behavioral data of patients, assisting clinicians in more accurately assessing changes in a patient's condition and developing personalized treatment plans. For instance, Yeom et al. [?] developed a digital therapy focused on emotional circadian rhythms. By integrating multi-dimensional information collected from wearable devices—including activity data, sleep parameters, heart rate indicators, and light exposure levels—this system can not only accurately predict the risk of mood episodes but also formulate individualized intervention plans based on identified episode patterns and circadian characteristics. This approach effectively prevents mood episodes and improves the overall quality of life for patients.

Similarly, another study utilized wearable devices to collect sleep data and employed mathematical models to indirectly infer light exposure, thereby estimating daily circadian phases. The results indicated that circadian phase disturbances in patients with Bipolar I Disorder typically precede changes in mood symptoms, suggesting a significant causal relationship between the two. This implies that clinicians can monitor disease progression based on circadian rhythm data and determine whether mood symptoms are triggered by circadian disruptions. Consequently, targeted interventions, such as sleep adjustment and light therapy, can be implemented.

Long-term monitoring of sleep and circadian rhythm data also serves as a valuable tool for predicting patient prognosis. If a patient's circadian rhythm remains persistently disrupted and difficult to correct, it suggests a high likelihood of recurrent mood episodes and a poor prognosis. Conversely, an improvement in circadian stability indicates a more favorable outlook. Furthermore, the integration of wearable technology with Virtual Reality (VR) has opened new avenues for the psychological treatment of bipolar disorder. A systematic review by Pablo et al. [?] demonstrated that VR interventions are significantly effective in improving cognitive function, depressive symptoms, emotion regulation, biological rhythm stability, and stress management in patients with bipolar disorder, while maintaining high levels of safety and patient adherence.

This technological breakthrough provides an immersive alternative to traditional psychotherapy, further expanding the comprehensive treatment models available for bipolar disorder. Regarding depressive disorders, the application of wearable technology has also extended into therapeutic interventions. These devices can monitor physiological indicators such as heart rate and skin conductance in real-time. Through instantaneous feedback, they help patients become aware of their stress levels and assist them in learning relaxation techniques—such as deep breathing or mindfulness meditation—thereby enabling more effective stress management and emotional regulation.

Similarly, wearable devices such as smartwatches can assess a patient's mood,

sleep, and activity levels in real-time, serving as an auxiliary tool for Cognitive Behavioral Therapy (CBT). Furthermore, wearable technology can be integrated with treatments such as Electroconvulsive Therapy (ECT) to provide new pathways for evaluating clinical efficacy in depression. For example, Powell et al. [?] utilized a wearable device originally designed for motor monitoring in Parkinson's disease (the Parkinson KinetiGraph, PKG) to monitor the degree of bradykinesia and the proportion of immobility time in patients with major depressive disorder before and after receiving ECT. This approach provides a quantitative basis for judging the efficacy of ECT, effectively addressing the limitations of traditional subjective assessment methods.

Wearable technology also plays a significant role in the prognostic assessment of depression. One study utilized Fitbit devices to conduct a longitudinal observation of patients with recurrent depression over a period of 541 days. By collecting sleep-related data, the results demonstrated that:

Increased sleep fragmentation is associated with the worsening of depressive symptoms, while increased variability in sleep parameters is linked to a higher probability of depression recurrence. Theoretically, if effective interventions are implemented in a timely manner to reduce sleep variability, the risk of depression relapse could be reduced by approximately 20%. This finding fully demonstrates the significant value of wearable technology in assessing the risk of depression recurrence.

Wearable devices are not only utilized for monitoring and auxiliary treatment but can also serve directly as therapeutic instruments. For instance, clinical trials conducted by Swanson et al. demonstrated that portable light therapy glasses (used for 60 minutes per day over a period of 5 weeks) significantly improved depressive symptoms in patients with postpartum depression. Furthermore, participants exhibited high levels of acceptance and tolerance toward the light therapy equipment .

In addition to light therapy, repetitive transcranial magnetic stimulation (rTMS) is widely applied in the treatment of psychiatric disorders. However, the application of traditional rTMS equipment has been severely restricted due to its large physical footprint and high power requirements. Recently, Qi developed the world's first battery-powered wearable rTMS device, providing a more convenient therapeutic option for the treatment of psychiatric conditions such as depressive disorders.

. Cutting-edge research progress further indicates that wearable brain-computer interface (BCI) devices can achieve individualized closed-loop regulation for depressive disorders. These devices are capable of both diagnostic detection and real-time individualized therapeutic intervention. For instance, a wearable BCI device developed by Zhao Guangli can accurately determine whether a patient has depression with an accuracy rate of up to 90%, all under non-invasive conditions that allow for rapid setup without the need for conductive paste. Furthermore, this device attempts to perform clinical subtyping and precision inter-

vention for patients with depressive disorders, achieving individualized physical regulation through the precise decoding of brain signals.

In summary, wearable technology holds broad application prospects in the treatment of depressive disorders. It can not only help patients better manage stress and regulate emotions through real-time monitoring and feedback but also serve as a direct therapeutic tool to provide individualized treatment plans for patients with depression. Future research must further validate the safety and efficacy of these technologies to promote their widespread clinical application.

In the management of anxiety disorders, the application of wearable technology provides patients with real-time and personalized intervention methods. A primary challenge in treating anxiety disorders is that patients frequently experience sudden-onset anxiety attacks, which traditional intervention measures often fail to address in a timely manner.

By monitoring physiological indicators such as heart rate and skin conductance in real-time, wearable devices can rapidly initiate intervention protocols upon detecting signs of anxiety. For instance, when an abnormal elevation in heart rate is detected, the device can immediately guide the user through deep breathing exercises. This form of instantaneous intervention not only effectively alleviates acute anxiety symptoms but also assists users in establishing healthier long-term coping mechanisms through consistent use.

Furthermore, beyond serving as auxiliary tools, wearable devices can be directly applied to the clinical treatment of anxiety disorders. For example, TouchPoints wristbands utilize gentle bilateral vibrations to generate alternating stimulation, which modulates the electrical activity of brain networks and significantly reduces anxiety symptoms. This non-invasive therapeutic approach offers a novel solution for anxiety management, particularly for patients who may have concerns regarding pharmacological treatments.

Finally, wearable technology can provide an objective empirical basis for clinical decision-making in the treatment of anxiety disorders through the continuous monitoring of real-time physiological data.

Physicians can dynamically adjust medication regimens or implement psychological interventions based on data collected by these devices, thereby enhancing the precision and effectiveness of treatment. Furthermore, long-term data tracking facilitates the evaluation of therapeutic outcomes and assists in prognostic assessment. However, the application of wearable technology in the management of anxiety disorders remains in an exploratory phase, and substantial future research is required to drive its further development.

Wearable technology has also demonstrated significant clinical value in the auxiliary treatment of mental disorders such as Obsessive-Compulsive Disorder (OCD), Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD), and Post-Traumatic Stress Disorder (PTSD). For instance, Klein et al. developed a multimodal sensor system—comprising an electrocardio-

gram (ECG) chest strap, motion sensors, and eye-tracking glasses—designed to support cognitive behavioral therapy for patients with OCD. Similarly, Voss et al. developed a wearable social learning aid for children with ASD. This tool utilizes Google Glass and a smartphone application to detect facial expressions and reinforce social cues, resulting in a significant improvement in the social capabilities of children with ASD .

Du Bois et al. utilized wearable neurotechnology based on low-cost EEG to conduct neurofeedback training. By increasing the amplitude of brain waves during the resting state, they significantly alleviated symptoms in patients with Post-Traumatic Stress Disorder (PTSD). This approach provides a feasible and cost-effective therapeutic method for the improvement of PTSD symptoms .

However, the current body of research regarding the use of wearable technology in the auxiliary treatment of other mental disorders remains limited. Future studies must further explore the efficacy of these technologies across various types of psychiatric conditions to optimize their application within clinical practice.

5 Advantages and Challenges

5.1 Advantages

Wearable technology holds broad application prospects in the field of mental health, offering several key advantages. (1) Real-time and continuous monitoring: Wearable devices can monitor and continuously collect biometric information, such as heart rate, heart rate variability (HRV), and electrodermal activity (EDA), in real time. This uninterrupted data collection facilitates the early detection of abnormalities, enabling timely interventions. (2) Portability: Most wearable devices are designed to be lightweight and easy to wear or carry, ensuring they do not cause significant inconvenience to the user's daily life. (3) Telemedicine support: Data can be transmitted to medical terminals in real time to support remote monitoring and assessment. This significantly improves medical efficiency, particularly for patients requiring long-term follow-up. (4) Individualization and interactivity: Based on the user's individual characteristics, wearable devices can provide personalized health recommendations and early warnings, facilitating precision medicine and better meeting the diverse needs of different patients.

5.2 Challenges

Despite the significant potential of wearable technology in the field of mental disorders, several challenges remain. (1) Data quality issues: Factors such as motion artifacts, environmental interference, and individual physiological differences can limit the data collection accuracy of wearable devices, thereby undermining the reliability and application value of research findings. To improve the quality of wearable technology data, researchers can employ various methods

to optimize data processing workflows. First, by setting thresholds, performing artifact correction, and conducting signal quality assessments, abnormal data can be effectively identified and removed, thus enhancing data reliability. Second, the signal-to-noise ratio can be further improved through personal baseline comparisons, filtering during similar activities, and Z-score normalization. Furthermore, researchers should prioritize the use of externally validated wearable devices and provide detailed reports on data quality and raw data in their studies, which helps in more accurately evaluating device performance. Currently, comprehensive and unified industry standards specifically for physiological data collection via wearable devices have not yet been established domestically or internationally; however, ongoing research and practice in related fields are laying the foundation for such standard-setting. (2) Technical applicability limitations: Poor compliance among specific populations (such as patients in the acute phase of psychotic symptoms) and reduced device tolerance during long-term monitoring significantly limit the promotion of wearable technology across various mental disorder groups. Consequently, device development must follow a “patient-centered” design philosophy, enhancing clinical applicability by optimizing human-computer interfaces and wearing comfort. (3) Barriers to clinical translation: Most existing evidence comes from small-sample exploratory studies and lacks validation from multicenter randomized controlled trials. Future large-sample empirical studies using standardized clinical validation frameworks are needed to confirm clinical utility. (4) Regulatory and ethical dilemmas: Currently, only 10% to 15% of wearable mental health devices worldwide have achieved medical-grade certification, and the privacy protection systems for biometric data remain incomplete. These data are highly identifiable and easily collected; if misused, they could cause irreversible harm to individuals. Therefore, there is an urgent need to establish specialized certification pathways and ethical review mechanisms. At the international level, the regulatory systems in the European Union and the United States are relatively mature. The EU’s Medical Device Regulation (MDR) centers on comprehensiveness and patient safety, providing a rigorous regulatory framework that emphasizes the integrity of clinical trials and strict market surveillance. In contrast, the U.S. Food and Drug Administration (FDA) employs the principle of “substantial equivalence,” allowing some products to reduce clinical data requirements by comparing them to already marketed products, resulting in shorter review times and higher flexibility. Both models offer distinct advantages and provide important references for the regulation of wearable mental health devices. Compared to these mature international systems, China still faces gaps in the regulation of wearable mental health devices. First, China has not yet issued specific laws, regulations, or guidelines for such devices; current supervision relies primarily on general medical device regulations, leading to a lack of specificity and clarity in the oversight of certain equipment. Regarding data privacy protection, China’s current laws have not yet formed a systematic protection mechanism and remain under the general framework of personal information protection. Compared with the EU’s General Data Protection Regulation (GDPR), there is a significant gap in the refinement and systematization of biometric data protection in China, making

it difficult to fully address the privacy risks posed by wearable mental health devices.

6 Summary

Wearable technology has demonstrated significant application value and promising prospects in the diagnosis and treatment of mental disorders. By continuously monitoring multi-dimensional physiological and behavioral indicators to construct digital phenotypes, these technologies have opened innovative pathways for early identification, symptom assessment, and precision intervention. However, current technological development remains in a critical stage of overcoming core difficulties and faces numerous challenges that require urgent resolution. Future research directions should focus on: (1) developing multi-modal sensor arrays with high reliability and validity; (2) establishing large-sample longitudinal databases; (3) optimizing deep learning algorithmic models; (4) constructing cross-modal, multi-dimensional diagnostic models based on wearable data; (5) formulating guidelines for clinical translational applications; (6) developing active intervention technologies, such as closed-loop feedback devices based on real-time emotion monitoring (e.g., automatically triggering intervention protocols upon detecting anxiety attacks), rather than remaining limited to passive monitoring; and (7) specialized adaptation for pediatric and geriatric populations, such as low-stimulation device designs for children with Autism Spectrum Disorder (ASD) and usability optimization for elderly patients with Alzheimer's disease, reflecting the need for age-appropriate technological modifications. With continuous technological breakthroughs and in-depth clinical validation, wearable technology is expected to become a key component of the mental disorder diagnosis and treatment system, driving mental health services toward a preventive, precise, and intelligent future.

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