ACCSCIENCE PUBLISHING

Eurasian Journal of Medicine and Oncology

REVIEW ARTICLE

Advancements in functional near-infrared spectroscopy applications for prefrontal cortex dysfunction in neuropsychiatric disorders

Yanan Wang[1,2,3†], Xiaofei Niu[4†], Yang Li[1,2,3], Xiaoyun Liu[1,2*], and Xin Guo[1,2,3*]

[1]Department of Neurology, The First Hospital of Hebei Medical University, Shijiazhuang, Hebei, China

[2]Department of Neurology, Hebei Hospital of Xuanwu Hospital, Capital Medical University, Shijiazhuang, Hebei, China

[3]Neuromedical Technology Innovation Center of Hebei Province, Shijiazhuang, Hebei, China

[4]Department of Traditional Chinese Medicine, Huanghua Municipal People's Hospital, Cangzhou, Hebei, China

Abstract

Many neuropsychiatric disorders arise from impairments in complex higher-order cognitive functions. However, current clinical diagnosis and treatment approaches still rely heavily on subjective rating scales, lacking objective, quantifiable, and reproducible assessment tools. The prefrontal cortex (PFC), as a central hub for executive function, attentional control, and emotional regulation, has been closely linked to a range of neuropsychiatric conditions, including depression, attention-deficit/hyperactivity disorder, schizophrenia, and autism spectrum disorder. This positions the PFC as a promising target for early diagnosis, mechanistic studies, and treatment evaluation. In recent years, functional near-infrared spectroscopy (fNIRS) has gained rapid traction in psychiatric neuroimaging research due to its non-invasiveness, high temporal resolution, portability, and cost-effectiveness. Empirical studies have demonstrated that fNIRS can detect reduced prefrontal activation in patients with depression, distinguish activation patterns among different disorders, and assist in evaluating the effects of neuromodulatory interventions such as transcranial direct current stimulation, transcranial alternating current stimulation, and neurofeedback training. Moreover, fNIRS-derived hemodynamic indicators often correlate with symptom severity. This review provides a comprehensive summary of recent advances in the application of fNIRS in PFC dysfunction-related neuropsychiatric disorders, focusing on activation characteristics, task paradigms, potential biomarkers, and integration with other imaging modalities. The review also discusses the diagnostic and prognostic potential of fNIRS, its current technical limitations, and future directions, aiming to support its clinical translation in the field of psychiatry.

Keywords: Functional near-infrared spectroscopy; Prefrontal cortex; Neuropsychiatric disorders; Advanced cognitive function; Clinical diagnosis; Treatment efficacy evaluation

†*These authors contributed equally to this work.*

***Corresponding authors:**
Xiaoyun Liu (57404217@hebmu.edu.cn);
Xin Guo (59003702@hebmu.edu.cn)

Citation: Wang Y, Niu X, Li Y, Liu X, Guo X. Advancements in functional near-infrared spectroscopy applications for prefrontal cortex dysfunction in neuropsychiatric disorders. *Eurasian J Med Oncol*. 2026;10(2):025190179. doi: 10.36922/EJMO025190179

Received: May 8, 2025

Revised: June 19, 2025

Accepted: July 4, 2025

Published online: August 1, 2025

1. Introduction

Neuropsychiatric disorders constitute a broad category of illnesses that profoundly affect individuals' emotional well-being, cognitive performance, and social functioning. Common conditions in this category include depression, schizophrenia, attention-deficit/hyperactivity disorder (ADHD), and autism spectrum disorder (ASD). These disorders not only impair quality of life but also impose a growing public health and socioeconomic burden as their prevalence continues to rise globally. Despite the diversity in clinical symptoms and diagnostic criteria, increasing evidence suggests that many of these conditions share common neurobiological underpinnings. In particular, functional abnormalities in the prefrontal cortex (PFC) have been repeatedly implicated, suggesting the presence of converging pathophysiological mechanisms across different diagnostic categories.

In recent years, neuropsychiatric disorders have increasingly been suggested as overlapping spectrums of dysfunction rather than strictly discrete disease entities. Shared impairments are commonly observed across diagnostic boundaries, including deficits in executive control, emotional regulation, social cognition, and attention.[1-3] These symptom dimensions are underpinned by dysregulation of large-scale brain networks, especially involving the PFC and its connectivity with limbic, striatal, and parietal regions.[4,5] Transdiagnostic neuroimaging studies have revealed convergent patterns such as reduced task-related prefrontal activation and disrupted resting-state connectivity,[6,7] reinforcing the view that PFC dysfunction may constitute a central neural mechanism across multiple psychiatric conditions.

In addition to cognitive and affective symptoms, neuropsychiatric disorders frequently present with high rates of comorbidities, chronic courses, and treatment resistance. Recent epidemiological data indicate that around 30% of individuals with major depressive disorder (MDD) meet the criteria for treatment-resistant depression, defined as non-response to at least two adequate pharmacological interventions.[8] Meanwhile, schizophrenia's negative symptom domain – characterized by apathy, social withdrawal, and diminished motivation – remains resistant to most standard antipsychotic treatments and strongly predicts poor functional outcomes.[9] These unmet clinical needs highlight the urgent demand for objective, neurobiologically grounded biomarkers capable of facilitating early detection, differential diagnosis, and personalized treatment monitoring.

The PFC is regarded as one of the most evolutionarily and functionally advanced regions of the human brain.[10] It plays a central role in regulating a wide range of high-level cognitive functions, including executive control, decision-making, working memory, attentional modulation, and emotional regulation.[11,12] Anatomically and functionally, it serves as a key integrative hub within large-scale brain networks. Disruption of PFC function has been strongly associated with the onset and progression of various neuropsychiatric disorders, as demonstrated by neuroimaging, electrophysiological, and neuropsychological studies.[11,13,14] Therefore, advancing our understanding of PFC dysfunction holds significant promise for uncovering the neural mechanisms underlying psychiatric symptoms, improving diagnostic precision, and developing targeted therapeutic approaches.

Traditional non-invasive neuroimaging methods, such as functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG), whereas informative, are often hindered by high cost, limited portability, or patient compliance issues.[15] These limitations make it challenging to capture dynamic brain activity in real-life or ecologically valid settings, particularly in pediatric or clinical populations. In contrast, functional near-infrared spectroscopy (fNIRS) has emerged as a promising imaging modality in both experimental and clinical neuroscience. This optical technique measures changes in oxygenated and deoxygenated hemoglobin concentrations within the cortex, providing an indirect yet sensitive indicator of neural activity. With its advantages of non-invasiveness, cost-efficiency, ease of use, and tolerance to motion, fNIRS is well-suited for investigating PFC function under various cognitive and affective task paradigms,[16] especially in populations with special needs or limited tolerance for traditional imaging.

In this context, delineating both shared and disorder-specific PFC dysfunction using neuroimaging tools such as fNIRS can substantially advance translational psychiatry and precision mental health efforts. This review aims to summarize recent research on neuropsychiatric disorders involving PFC dysfunction using fNIRS, and to evaluate the current applications and future prospects of this technology. We first introduce the basic structure and functions of the PFC, along with the principles of fNIRS. We then systematically review empirical findings from fNIRS studies targeting disorders primarily associated with PFC dysfunction. Finally, we discuss the limitations of current research, the technical challenges of fNIRS, and future directions. Through this review, we hope to provide a comprehensive perspective on how fNIRS contributes to the understanding of neuropsychiatric disorders and its potential for future clinical applications in mental health.

2. Overview of the PFC

2.1. Anatomical structure of the PFC

Anatomically, PFC is located at the most anterior part of the brain and includes all regions of the frontal lobe

except for the primary and secondary motor cortices.[10,12] It is one of the most highly developed and structurally complex areas of the human brain, primarily composed of pyramidal neurons and inhibitory interneurons. Pyramidal neurons are responsible for information transmission, whereas inhibitory neurons regulate the strength of this transmission.[10-12] The PFC is richly connected with other brain regions – including the sensory and motor cortices, amygdala, hippocampus, basal ganglia, and thalamus – forming a complex neural network that supports high-level cognitive functions.[17-19] It also exhibits strong plasticity; its structure and function change significantly during development, and even in adulthood, its connectivity and activity can adapt in response to experience and environmental factors.[20]

2.2. Main functions of the PFC

The PFC plays a central role in regulating higher-order cognitive functions through its extensive connections with other brain areas. These functions include executive control, attention, emotion regulation, social behavior, decision-making, and problem-solving,[21] thereby influencing an individual's thoughts, emotions, and behaviors. For example, sustained attention has been shown to be significantly affected by levels of gamma-aminobutyric acid and glutamate-glutamine in the PFC.[22,23] Numerous studies have demonstrated that the PFC – especially the ventromedial PFC – interacts with the ventral striatum and amygdala to support reward processing and value-based decision-making. Its connections with the posterior cingulate cortex, precuneus, dorsomedial PFC, and amygdala also play key roles in various aspects of social cognition.[24,25] Functionally, the PFC can be divided into several subregions. The dorsolateral PFC (DLPFC), which includes both dorsolateral and ventrolateral subareas,[26] is crucial for executive functions – a broad term encompassing inhibitory control, working memory, and cognitive flexibility, first conceptualized in clinical neuropsychology.[13,14,27-29] The ventromedial PFC is mainly involved in emotion regulation, social cognition, and decision-making, whereas the orbitofrontal cortex is associated with emotion, motivation, and social behavior. The cingulate cortex plays a role in conflict monitoring, error detection, and conscious awareness.[25]

3. Overview of fNIRS technology

3.1. Principles of fNIRS

fNIRS is a non-invasive optical imaging technique that detects cortical hemodynamic responses by measuring changes in the absorption of near-infrared light (700 – 900 nm) by oxygenated hemoglobin (HbO) and deoxygenated hemoglobin.[16,30,31] Neuronal activity leads to increased regional cerebral blood flow, causing a rise in HbO and a drop in deoxygenated hemoglobin, which can be quantified in real time using the modified Beer–Lambert law.

fNIRS systems generally employ three types of light sources: light-emitting diodes, laser diodes, and superluminescent diodes, which vary in cost, signal quality, and application scope.[32] Continuous-wave fNIRS, the most common and portable system, typically uses light-emitting diodes to estimate relative changes in blood oxygenation. Frequency-domain systems use laser diodes to measure absolute concentration by modulating light intensity and separating absorption from scattering. Time-domain systems use superluminescent diodes and ultrashort light pulses to calculate light travel time, offering more precise imaging of tissue properties and oxygenation. These technological variations enable fNIRS to be adapted for diverse experimental and clinical contexts.[32,33]

3.2. Advantages of fNIRS

Human neural activity is a dynamic and intricately coordinated process. To gain deeper insight into its nature, research must go beyond controlled laboratory settings and consider real-world behavioral contexts. Neuropsychiatric studies, in particular, should place greater emphasis on everyday life situations. fNIRS, with its multiple advantages, has been widely used in both clinical and experimental settings. It is entirely non-invasive – requiring no contrast agents or injections – which ensures participant safety.[31] Moreover, most fNIRS systems are portable, easy to install, and tolerant of movement, making them suitable for diverse environments, including clinical and non-clinical contexts, and especially advantageous for studying special populations such as infants and young children.[34] Compared with other neuroimaging modalities, fNIRS offers numerous benefits (Table 1). It is relatively low-cost and easy to operate, making it a cost-effective tool. fNIRS also has excellent compatibility with other techniques, allowing researchers to enhance both spatial and temporal resolution or obtain complementary information under different conditions. At present, fNIRS is frequently used for both experimental research and clinical diagnostics. In research, it is employed to study various dimensions of brain activity, particularly the relationship between neural processes and changes in cerebral blood flow and oxygenation. It has proven valuable in investigating complex cognitive tasks, sensory processing, and neuroplasticity. Clinically, fNIRS is used for diagnosing neuropsychiatric disorders such as epilepsy and depression, monitoring cerebral oxygenation during post-operative or rehabilitation stages in stroke patients, and evaluating the effects of non-invasive neuromodulation techniques.

Table 1. Advantages of functional near-infrared spectroscopy and other neuroimaging modalities

Characteristic	Functional near-infrared spectroscopy	Electroencephalogram	Functional magnetic resonance imaging	Magnetoencephalography
Principle	Near-infrared light penetrates tissue, measures blood oxygen changes	Electrodes measure neural electrical activity on the skin's surface	Magnetic field detects blood oxygen level-dependent signals	Magnetic field detects neural activity in the brain
Target population	Infants, the elderly, and individuals with limited mobility	All people, especially epilepsy patients	Suitable for a wide range of individuals; requires tolerance of confined spaces	Special populations: neuroscience researchers
Data collection environment	Portable device, suitable for natural settings or bedside monitoring	Laboratory, clinical environment	Dedicated laboratory, requires fixed equipment	Dedicated laboratory
Invasiveness	Non-invasive	Non-invasive	Non-invasive	Non-invasive
Portability	Portable	Portable	Not portable	Not portable
Sensitivity to movement	Low, tolerates movement	Low	High	Low
Spatial resolution	Moderate (2 – 3 cm)	Low (a few centimeters)	High (sub-millimeter level, around 1 mm)	High (millimeter level)
Temporal resolution	Low (a few seconds)	High (millisecond level)	Low (a few seconds to 1 – 2 min)	High (millisecond level)
Cost	Low to moderate	Low	High	Very high
Common applications	Cognitive function, emotion research, and clinical monitoring	Neural activity, epilepsy, and sleep research	Deep brain function imaging, clinical diagnosis	Neural function research

fNIRS can be combined with various techniques for multimodal assessment, including electroencephalogram (EEG), fMRI, and magnetoencephalography.[35] It can also be integrated with neuromodulation methods such as transcranial magnetic stimulation to evaluate brain responses following stimulation.[36] Among these, the fNIRS-EEG combination is the most widely used. While fNIRS provides information on hemodynamic responses, EEG offers high temporal resolution to capture rapid neuronal firing. This combination is extensively applied in cognitive studies of neuropsychiatric conditions – such as attention, working memory, and emotion regulation – as well as in sleep research. With the advancement of machine learning and artificial intelligence, data fusion algorithms are becoming more sophisticated, enabling more accurate and reliable integration of different modalities. As a result, the development and application of wearable fNIRS-EEG-based brain–computer interface devices have become a major focus in contemporary neuroscience research.[37-39]

3.3. Disadvantages of fNIRS

Although fNIRS technology has achieved promising results and is widely applied, it remains in a developmental stage and faces several technical challenges. One major limitation is its relatively low spatial resolution, which typically spans several centimeters,[32,33] making it difficult to accurately localize small brain regions. In addition, the limited penetration depth of near-infrared light restricts fNIRS in studying superficial cortical areas, rendering deeper brain structures inaccessible.[40,41] The measurement accuracy is also susceptible to various sources of interference, including dark-colored scalp, hair, and physiological signals such as respiration and heartbeat, all of which can affect signal quality and complicate data interpretation.[42]

Another significant challenge lies in the complexity of data processing. fNIRS results usually require extensive preprocessing and correction, often involving advanced algorithms and statistical techniques, which demand a high level of technical expertise from researchers.[43] Moreover, studies have pointed out that most fNIRS research tends to focus on verbal fluency tasks using multichannel systems targeting the PFC. Verbal fluency tasks are commonly used to assess language generation and executive function by asking participants to produce as many words as possible within a time limit, starting with a given letter or belonging to a specific category.[44] However, the over-reliance on this paradigm has led to a lack of diversity in experimental tasks and may introduce selection bias,[44] especially by excluding participants with speech impairments who are unable to perform verbal tasks.[45,46]

Despite these challenges, fNIRS technology continues to evolve. For example, a research team at Beihang University of Aeronautics and Astronautics has recently

made significant progress by overcoming the imaging limitations posed by dark hair and improving the spatial resolution of fNIRS to approximately 5 mm,[47] marking an important advancement in both research capability and potential clinical applications.

4. Relevant advancements in studies of neuropsychiatric disorders

The PFC plays a central role in regulating higher-order cognitive functions in humans. Dysfunction in this region can lead to widespread impairments across multiple systems, contributing to a range of neuropsychiatric disorders and cognitive impairments. As a non-invasive brain imaging technique with high temporal and spatial resolution, fNIRS has gained increasing attention in clinical research. It has been extensively used to investigate pathological mechanisms, assist in clinical and differential diagnosis, and evaluate treatment outcomes.

4.1. Depression

Major depressive disorder refers to a group of clinical conditions primarily characterized by low mood. Its symptoms can be broadly categorized into three groups: core symptoms, psychological symptoms, and somatic symptoms. In addition to depressed mood and anhedonia, many patients also experience anxiety, cognitive impairments, negative thinking patterns, and sleep disturbances.

A large body of evidence has demonstrated reduced HbO concentrations in the DLPFC, the ventrolateral PFC, and frontopolar cortex (FPC) among individuals with depression, particularly during tasks that require executive function, emotion regulation, or verbal fluency.[48-51] These reductions in cortical activation are closely associated with negative affect, impaired cognitive regulation, and difficulties in processing emotional facial expressions. Manelis *et al.*[47] further reported that negative cognitive patterns in depression are linked to hypoactivation of the PFC, particularly the right DLPFC, which may underlie impairments in emotional facial recognition and increased emotional reactivity.[28] Notably, some studies have observed compensatory hyperactivation in the FPC or recruitment of alternative motor-related regions, possibly due to reduced baseline PFC function.[52] Moreover, fNIRS has been employed to examine functional connectivity within large-scale networks, revealing disruptions in the default mode network and diminished coherence between prefrontal regions and posterior cortical areas.[53]

Beyond identifying general patterns of hypoactivation, fNIRS has also shown promise in distinguishing between subtypes of depression and capturing symptom-specific neural alterations. For instance, Wu *et al.*[53] reported significant differences in PFC activation patterns between anxious and non-anxious depressive subtypes, particularly in the right DLPFC and FPC regions.[54,55] Sleep disturbance, a common comorbidity in MDD, has been linked to altered function in the left ventrolateral PFC. fNIRS studies have demonstrated that insomnia severity is positively correlated with regional activation levels, suggesting compensatory or maladaptive prefrontal recruitment during sleep-related cognitive load.[56]

Recent investigations have expanded the use of fNIRS to stratify patients according to depression severity. While cortical hypoactivation is a consistent hallmark across the depressive spectrum, patients with moderate depression have been shown to exhibit more profound reductions in PFC activity than those with mild symptoms.[50,51,57-59] This gradation in hemodynamic response may reflect underlying neurobiological burden and can potentially serve as a biomarker for staging and individualized treatment planning. Furthermore, fNIRS studies have identified distinct prefrontal activation profiles between depressed individuals with and without suicidal ideation. Patients experiencing suicidal thoughts tend to show significantly lower activation in the dorsomedial and ventrolateral PFC during cognitive and emotional tasks,[57] underscoring the potential of fNIRS as a non-invasive tool for suicide risk assessment.

In addition to diagnosis and classification, fNIRS has been utilized to monitor changes in cortical function following therapeutic interventions. For example, several studies have employed fNIRS to track activation patterns before and after pharmacological treatment, cognitive behavioral therapy, or neuromodulation techniques such as transcranial magnetic stimulation.[36,60] In many cases, clinical symptom improvement is accompanied by the normalization of prefrontal activation, indicating that fNIRS may serve as an effective tool for treatment evaluation and longitudinal follow-up.

Although many studies consistently report decreased HbO levels in the PFC of individuals with depression, the specific activation patterns vary considerably between individuals. These differences may be influenced by task design, clinical state (e.g., acute episode versus remission), and comorbid conditions such as anxiety and insomnia. In addition, variability in paradigms – such as verbal fluency tasks versus working memory tasks – can reduce the comparability of results across studies. Future research should aim to standardize task protocols, account for depression subtypes, and control for comorbidities to improve the reproducibility and clinical utility of fNIRS findings in depression.

4.2. Schizophrenia

Schizophrenia is a severe and chronic psychiatric disorder characterized by widespread disruptions in cognition, emotion, and social behavior. Its underlying mechanisms have been closely linked to dysfunction in the PFC, which plays a central role in executive processes, attentional control, and social cognition. Among its core symptoms, disorganized thinking has been strongly associated with decreased activity in the DLPFC,[61] and working memory deficits remain one of the most consistent cognitive impairments observed in patients with schizophrenia.[62]

fNIRS studies have provided valuable insights into prefrontal abnormalities in schizophrenia, particularly during working memory paradigms such as the N-back task. Compared to healthy controls, patients with schizophrenia tend to perform significantly worse on these tasks and exhibit increased activation in the right FPC. This elevated response may reflect compensatory neural recruitment in response to baseline deficits in prefrontal efficiency.[63] In addition, reduced activation efficiency in the right medial PFC has been repeatedly linked to attentional impairments in schizophrenia.[64] fNIRS research has also demonstrated that patients with schizophrenia typically show lower cerebral blood flow in prefrontal regions,[65] along with a delayed onset of activation.[59] These temporal abnormalities suggest disrupted neurovascular coupling and altered cortical timing mechanisms, which may be specific to the disorder.

While PFC dysfunction is observed across several psychiatric conditions, schizophrenia may exhibit distinct neural signatures detectable by fNIRS. For instance, Diao *et al.*[65] reported that certain prefrontal subregions in schizophrenia patients showed lower activation than those in individuals with other disorders, such as depression and bipolar disorder, supporting the potential of fNIRS in differential diagnosis.[59,66]

In terms of treatment monitoring, fNIRS has also been used to examine the effects of pharmacological and non-pharmacological interventions. Antipsychotic medication remains the cornerstone of schizophrenia treatment, and within therapeutic ranges, a negative correlation has been observed between drug dosage and error rates in working memory tasks. fNIRS evidence suggests that this may be due to medication-induced modulation of DLPFC hemodynamics. Moreover, studies combining high-definition transcranial direct current stimulation with cognitive tasks such as the N-back paradigm have demonstrated promising results in alleviating negative symptoms and enhancing prefrontal activation.[67]

Beyond cognitive symptoms, fNIRS is increasingly being applied to investigate social cognitive deficits in schizophrenia – such as impairments in emotion recognition, perspective-taking, and gaze-following – which significantly limit patients' real-world functioning. In one study involving eye-contact tasks, first-episode psychosis patients showed absent activation in the right temporo-parietal junction and compensatory recruitment in the left hemisphere, patterns that were correlated with poor social functioning.[68] These findings suggest that fNIRS can capture lateralized abnormalities in social information processing. Earlier studies have also reported significant correlations between lateral PFC activity and theory-of-mind performance,[62] further supporting the involvement of prefrontal regions in social cognition.

Several intervention studies have integrated fNIRS to assess treatment-related changes in brain function. For example, the InMotion program – an integrated 12-week intervention combining physical exercise, cognitive training, and social engagement – used fNIRS to monitor PFC activation in schizophrenia patients. Post-intervention data revealed increased hemodynamic response in the DLPFC, accompanied by reductions in negative symptoms and improved social functioning.[69] Similarly, Ma *et al.*[66] employed a 48-channel fNIRS to demonstrate that functional targeting with high-definition transcranial direct current stimulation effectively enhances activation in the left DLPFC, supporting its utility in neuromodulation strategies for improving social cognition.[67]

Overall, fNIRS studies in schizophrenia consistently reveal reduced PFC activation in working memory and during attentional tasks, particularly in the right DLPFC and medial PFC. Compared to MDD, prefrontal abnormalities in schizophrenia appear more closely associated with core cognitive symptoms such as executive dysfunction and attentional dysregulation. Some studies have also reported delayed activation timing, suggesting disease-specific disruptions in cortical dynamics. However, the interpretation of fNIRS findings remains complex – while some researchers view increased activation as a compensatory mechanism, others interpret it as inefficiency or dysregulation – highlighting the lack of a unified physiological explanation. In addition to this interpretive ambiguity, multiple confounding variables – such as symptom heterogeneity, medication status, and dominance of negative versus positive symptoms – complicate the extraction of generalizable patterns. Future research should prioritize subgroup analyses based on clinical phenotypes, employ dynamic and socially relevant task paradigms, and integrate multimodal imaging (e.g., EEG and fMRI) to further

elucidate the pathophysiological basis of prefrontal dysfunction in schizophrenia.

4.3. Attention deficit hyperactivity disorder

Attention deficit hyperactivity disorder is primarily characterized by executive function deficits,[70] including impairments in inhibitory control, working memory, and cognitive flexibility. Patients often struggle to suppress irrelevant stimuli or impulsive behaviors, leading to distractibility, sustained attention problems, and academic difficulties. These symptoms have been linked to dysfunction of the locus coeruleus–norepinephrine system, which plays a key role in regulating the activity of the PFC and other brain regions.[23,71] As the PFC is critical for high-level cognitive control, fNIRS studies have revealed functional abnormalities in this region among individuals with ADHD, particularly reduced activation in DLPFC, which is considered a core contributor to executive dysfunction. For instance, Friedman *et al.*[71] found that children with ADHD showed significantly reduced DLPFC activity during a verbal working memory task, suggesting DLPFC's involvement in the cognitive deficits associated with the disorder.[72] However, Li *et al.*[72] proposed a different perspective based on fNIRS findings. In tasks involving magnitude judgment and task switching, they found that adults with ADHD showed a positive correlation between task-switching cost and oxyhemoglobin levels in the frontal eye field and orbitofrontal cortex, but a negative correlation with oxyhemoglobin levels in the DLPFC.[73] This suggests that task-switching costs in ADHD may be driven more by reactivity to automatic visual stimuli and impulsive responses than by deficits in higher-order cognitive processing. These results underscore the importance of cognitive state regulation in ADHD;[74] however, they challenge the classical view of executive dysfunction, pointing instead to altered sensory-motor processing as a potential core mechanism, offering a new direction for future research.

fNIRS has also shown promise as a diagnostic and evaluation tool for ADHD. Husain *et al.*[74] reported that prefrontal hemodynamic responses measured by fNIRS could distinguish ADHD patients from healthy controls with classification accuracies of 75.8% and 76%, respectively.[75] Similarly, Ortuno-Miro *et al.*[75] found that ultra-low-frequency fNIRS fluctuations in the PFC during rhythmic cognitive tasks effectively differentiated ADHD from non-ADHD groups,[76] suggesting that fNIRS-based hemodynamic markers may serve as potential functional biomarkers for the disorder. Beyond diagnosis, fNIRS is increasingly used to evaluate intervention effects. For example, studies have shown that neurofeedback training can help patients regulate DLPFC activity and improve attention. These improvements are not merely temporary – sustained training has been linked to lasting changes in activation and connectivity related to working memory, highlighting the potential of fNIRS-NF as a targeted intervention for executive deficits in ADHD.[77] In another study, Lu *et al.*[77] used fNIRS to assess the effects of transcranial alternating current stimulation and transcranial direct current stimulation (tDCS), finding improvements in inhibitory control and cognitive flexibility. tDCS, in particular, appeared more effective in enhancing neural efficiency in the right inferior frontal gyrus and PFC. In addition, transcutaneous electrical acupoint stimulation was also found to alleviate ADHD symptoms based on fNIRS measurements.[78,79]

Taken together, fNIRS research has established a consistent link between ADHD and PFC dysfunction, particularly reduced DLPFC activation during executive tasks. However, alternative findings have emerged, suggesting that some patients' brain activity may be more influenced by impulsivity or heightened sensory input, reflecting different neurocognitive pathways. This supports the idea that ADHD is not a unitary disorder but may involve multiple neurophysiological subtypes. While fNIRS has provided valuable insights into both diagnosis and treatment response, challenges remain in the standardization of biomarkers and data processing methods. Future research should incorporate diverse task paradigms, account for individual symptom profiles and behavioral data, and integrate neurofeedback mechanisms to move toward more precise and personalized functional imaging approaches for ADHD.

4.4. ASD

ASD is a neurodevelopmental disorder primarily characterized by social impairments, language development delays, restricted interests, and repetitive behaviors. ASD and ADHD are among the most severe neurodevelopmental disorders, with both conditions focusing on executive dysfunction.[80] While fNIRS data indicate that both ASD and ADHD patients show reduced PFC activation during tasks related to executive functions, the activation patterns differ between the two conditions. For example, compared to normal individuals, ADHD patients exhibit a global decrease in PFC activation during working memory tasks as assessed by fNIRS, whereas ASD patients show excessive activation in the right PFC. This suggests a close relationship between right hemisphere functional connectivity and working memory deficits in ASD patients.[81]

In terms of intervention, Chen *et al.*[81] found that applying tDCS during inhibitory control training significantly improved performance in individuals with ASD, with fNIRS

analysis supporting the observed effects.[82] Other fNIRS-based studies have shown that participation in structured physical activity programs can significantly activate DLPFC, orbitofrontal cortex, and frontopolar areas, enhancing functional connectivity within brain networks and improving executive function processing in children with ASD.[83] These findings highlight the potential of fNIRS as a tool to monitor treatment response in ASD interventions.

Overall, individuals with ASD exhibit more complex PFC activation patterns in fNIRS studies compared to those with ADHD, with overactivation in the right PFC being a frequently observed feature. This may reflect increased cognitive demands during social information processing or represent a compensatory mechanism. Like ADHD, ASD is associated with executive dysfunction, but the heterogeneity of its neural activation patterns makes it difficult to identify with a single task or metric. Some intervention studies, such as those involving tDCS or physical training, indicate that the PFC retains plasticity and that fNIRS may be a useful method for evaluating intervention outcomes. However, most existing research has focused on children, with limited data on developmental trajectories or long-term changes. Furthermore, key domains such as language function and emotion regulation remain underexplored in current fNIRS work. Future studies should integrate multidimensional behavioral assessments with fNIRS-based indicators to better characterize ASD-specific neural activity patterns and support early identification efforts.

4.5. Other neuropsychiatric disorders

Alzheimer's disease (AD) is the most common form of major neurocognitive disorder in the elderly, accounting for over 50% of all dementia cases. It is characterized by progressive cognitive decline and personality changes. fNIRS studies have shown significantly reduced PFC activation in AD patients,[84] with the DLPFC identified as a potential key site of cortical impairment.[85] Functional connectivity within the resting-state prefrontal network has also been found to decrease progressively across the AD spectrum.[85] Early detection and intervention are critical, and conditions such as mild cognitive impairment and subjective memory complaints are recognized as prodromal stages of AD. Lee *et al.*[85] demonstrated the feasibility of using fNIRS to distinguish individuals with SMC and MCI.[86,87] Furthermore, Zhang *et al.*[87] proposed a simplified fNIRS data processing approach to improve its practicality in early-stage AD screening.[88]

Parkinson's disease (PD) is a neurodegenerative disorder commonly affecting older adults, characterized primarily by resting tremor and postural-gait instability. fNIRS studies have revealed that PD patients show overactivation in the left DLPFC during verbal fluency tasks.[89] While walking, PFC hyperactivation may reflect a compensatory response aimed at supporting attentional and motor control to reduce fall risk.[90] The extent of this compensatory activation varies across motor subtypes,[91] and levodopa administration has been shown to further enhance left PFC activation during gait, improving cognitive resource allocation and motor performance.[92]

In the context of epilepsy, fNIRS has also demonstrated clinical utility. While diagnosis still primarily relies on EEG, its limited spatial resolution presents challenges. Khaksari *et al.*[69] suggested that the higher spatial resolution

Table 2. Summary of functional near-infrared spectroscopy research and clinical applications in major neuropsychiatric disorders

Disorder	Main task paradigm	Targeted PFC subregion	Key functional near-infrared spectroscopy findings	Clinical application
Major depressive disorder	Verbal fluency task, Emotional Stroop task	DLPFC, ventrolateral PFC, FPC	Reduced HbO in right DLPFC; severity-dependent hypoactivation; distinct patterns with suicide ideation	Diagnosis, symptom stratification, evaluation of neuromodulation (e.g., tDCS)
Attention deficit hyperactivity disorder	Go/No-Go Task, N-back Task, and continuous performance task	DLPFC, ventrolateral PFC, FPC	Reduced task-related HbO in right PFC; delayed activation; altered functional asymmetry	Treatment response tracking, subtype differentiation, and objective attention marker
Schizophrenia	N-back task, working memory tasks, social cognition tasks	DLPFC, medial PFC, OFC	Lower activation in medial PFC and right DLPFC; delayed hemodynamic response; reduced efficiency	Differential diagnosis, negative symptom tracking, and response to cognitive training
Autism spectrum disorder	Eye contact tasks, Theory of Mind, emotion recognition	DLPFC, OFC, temporoparietal junction	Reduced PFC activation during Theory of Mind and emotion recognition; atypical right temporoparietal junction response in social tasks	Social cognitive assessment, early screening, and potential aid in individualized intervention

Abbreviations: DLPFC: Dorsal prefrontal cortex; FPC: Frontopolar cortex; HbO: Oxygenated hemoglobin; OFC: Orbitofrontal cortex; PFC: Prefrontal cortex; tDCS: Transcranial direct current stimulation.

of fNIRS, particularly through the monitoring of cytochrome c oxidase levels, could offer valuable insights into mitochondrial dysfunction in epilepsy.[70] Combining EEG with fNIRS may provide a more comprehensive understanding – especially in pediatric epilepsy – by integrating electrophysiological and metabolic perspectives.

Therefore, fNIRS has revealed altered PFC activation patterns across AD, PD, and epilepsy, indicating the prefrontal region as a potential transdiagnostic marker of brain dysfunction. However, these patterns differ by condition. AD is associated with progressive loss of connectivity, while PD often shows increased activation due to compensatory mechanisms. These findings underscore the potential of fNIRS in identifying disease stages, tracking pathological progression, and understanding compensatory processes. Nonetheless, most current studies are exploratory, with limited focus on underlying mechanisms. Future work should aim to integrate fNIRS with complementary measures – such as neurotransmitter profiles, EEG rhythms, and metabolic markers – to develop condition-specific biomarker panels that enhance early detection and dynamic assessment.

5. Conclusion and future directions

As a non-invasive, portable, cost-effective neuroimaging technique with high temporal resolution, fNIRS has shown great promise in the study of various neuropsychiatric disorders involving PFC dysfunction. Across conditions such as depression, schizophrenia, ADHD, ASD, AD, PD, and epilepsy, numerous empirical studies have revealed altered PFC activation patterns, particularly in key regions such as the DLPFC, ventrolateral PFC, and FPC.[48,61,70,72,80,84,89] These changes are closely related to deficits in executive function, attention, and emotion regulation, reinforcing the central role of the PFC in the pathophysiology of mental disorders.[11,21,48,71] A summary of representative fNIRS findings and clinical implications across major neuropsychiatric disorders is presented in Table 2.

Reduced activation and impaired functional connectivity in the PFC appear to be common features across many psychiatric and neurological conditions, suggesting that this region may serve as a transdiagnostic neural marker with potential value for clinical diagnosis and treatment monitoring.[6,7,59,65] Moreover, fNIRS also reveals disease-specific activation patterns. For example, ADHD patients typically show widespread reductions in PFC activity, while individuals with ASD often exhibit overactivation in the right PFC.[72,80,81] Similarly, AD is characterized by a gradual decline in frontal connectivity, whereas PD patients may show increased PFC activation as a compensatory response to motor deficits.[85,89-91] This coexistence of shared and distinct patterns highlights the relevance of fNIRS for disorder subtyping, mechanistic exploration, and individualized treatment planning.

Nevertheless, current fNIRS research in psychiatry still faces several limitations. Inconsistencies in task paradigms, lack of standardized data processing pipelines, small and heterogeneous samples, and the predominance of cross-sectional designs all limit the comparability and generalizability of findings.[44,46] Moreover, most studies focus on the PFC, with limited investigation into deeper or broader brain network interactions. fNIRS signals are also susceptible to artifacts caused by hair, skin pigmentation, and motion, which can compromise data quality.[42]

Future efforts should aim to first improve spatial resolution and penetration depth to better capture subcortical and deeper cortical structures. In addition, advancing multimodal integration with EEG, fMRI, electrophysiology, and metabolic markers will allow a more comprehensive understanding of the brain structure and functions. Another priority is to establish standardized analysis pipelines and open-access databases to enhance data comparability and reproducibility. Moreover, applying artificial intelligence and machine learning to extract discriminative features from high-dimensional datasets could support clinical translation. Finally, promoting large-scale, multi-center, longitudinal studies will be essential to validate the stability and sensitivity of fNIRS metrics across disease stages, interventions, and individual variability.

In conclusion, fNIRS holds distinct advantages for uncovering PFC-related dysfunction in neuropsychiatric disorders. With ongoing advances in instrumentation, analytical techniques, and research design, fNIRS is well-positioned to play an increasingly central role in early detection, mechanistic insight, diagnostic support, and treatment evaluation, driving the field toward more precise assessments and personalized interventions in brain health.

Acknowledgments

None.

Funding

This work was supported by the National Nature Science Foundation of China (No. 82301458), the Nature Science Foundation of Hebei Province (No. H2024206372), the Hebei Province Government-funded Excellent Talents Project in Clinical Medicine (No. ZF2024147), the Medical Science Research Project of Hebei Province (No. 20230984 and 20240529), and the Project of Traditional Chinese Medicine of Hebei Province (No. 2023065), the "Spark"

scientific research project of the First Hospital of Hebei Medical University (No. XH202314).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Author contributions

Conceptualization: Yanan Wang
Writing – original draft: Yanan Wang, Xiaofei Niu, Yang Li
Writing – review & editing: Xiaoyun Liu, Xin Guo

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Not applicable.

References

1. McTeague LM, Goodkind MS, Etkin A. Transdiagnostic impairment of cognitive control in mental illness. *J Psychiatr Res*. 2016;83:37-46.

   doi: 10.1016/j.jpsychires.2016.08.001

2. Kebets V, Favre P, Houenou J, *et al*. Fronto-limbic neural variability as a transdiagnostic correlate of emotion dysregulation. *Transl Psychiatry*. 2021;11(1):545.

   doi: 10.1038/s41398-021-01666-3

3. Dugré JR, Eickhoff SB, Potvin S. Meta-analytical transdiagnostic neural correlates in common pediatric psychiatric disorders. *Sci Rep.* 2022;12(1):4909.

   doi: 10.1038/s41598-022-08909-3

4. Zhang B, Lin P, Wang X, *et al*. Altered functional connectivity of striatum based on the integrated connectivity model in first-episode schizophrenia. *Front Psychiatry*. 2019;10:756.

   doi: 10.3389/fpsyt.2019.00756

5. Sha Z, Wager TD, Mechelli A, He Y. Common dysfunction of large-scale neurocognitive networks across psychiatric disorders. *Biol Psychiatry*. 2019;85(5):379-388.

   doi: 10.1016/j.biopsych.2018.11.011

6. Boisvert M, Dugré JR, Potvin S. Patterns of abnormal activations in severe mental disorders a transdiagnostic data-driven meta-analysis of task-based fMRI studies. *Psychol Med*. 2024;54(13):1-12.

   doi: 10.1017/s003329172400165x

7. Doucet GE, Janiri D, Howard R, O'Brien M, Andrews-Hanna JR, Frangou S. Transdiagnostic and disease-specific abnormalities in the default-mode network hubs in psychiatric disorders: A meta-analysis of resting-state functional imaging studies. *Eur Psychiatry*. 2020;63(1):e57.

   doi: 10.1192/j.eurpsy.2020.57

8. Oliveira-Maia AJ, Bobrowska A, Constant E, *et al*. Treatment-resistant depression in real-world clinical practice: A systematic literature review of data from 2012 to 2022. *Adv Ther*. 2024;41(1):34-64.

   doi: 10.1007/s12325-023-02700-0

9. Marder SR, Umbricht D. Negative symptoms in schizophrenia: Newly emerging measurements, pathways, and treatments. *Schizophr Res*. 2023;258:71-77.

   doi: 10.1016/j.schres.2023.07.010

10. Preuss TM, Wise SP. Evolution of prefrontal cortex. *Neuropsychopharmacology*. 2022;47(1):3-19.

    doi: 10.1038/s41386-021-01076-5

11. Haber SN, Robbins T. The prefrontal cortex. *Neuropsychopharmacology*. 2021;47(1):1-2.

    doi: 10.1038/s41386-021-01184-2

12. Levy R. The prefrontal cortex: From monkey to man. *Brain*. 2024;147(3):794-815.

    doi: 10.1093/brain/awad389

13. Xu R, Bichot NP, Takahashi A, Desimone R. The cortical connectome of primate lateral prefrontal cortex. *Neuron*. 2022;110(2):312-327.e7.

    doi: 10.1016/j.neuron.2021.10.018

14. Popplau JA, Hanganu-Opatz IL. Development of prefrontal circuits and cognitive abilities. *Cold Spring Harb Perspect Biol*. 2024;16(10):a041502.

    doi: 10.1101/cshperspect.a041502

15. Huang B, Law MW, Khong PL. Whole-body PET/CT scanning: Estimation of radiation dose and cancer risk. *Radiology*. 2009;251(1):166-174.

    doi: 10.1148/radiol.2511081300

16. Rahman MA, Siddik AB, Ghosh TK, Khanam F, Ahmad M. A narrative review on clinical applications of fNIRS. *J Digit Imaging*. 2020;33(5):1167-1184.

    doi: 10.1007/s10278-020-00387-1

17. Parnaudeau S, Bolkan SS, Kellendonk C. The mediodorsal thalamus: An essential partner of the prefrontal cortex for cognition. *Biol Psychiatry*. 2018;83(8):648-656.

    doi: 10.1016/j.biopsych.2017.11.008

18. Pessoa L. A network model of the emotional brain. *Trends Cogn Sci*. 2017;21(5):357-371.

    doi: 10.1016/j.tics.2017.03.002

19. Kenwood MM, Kalin NH, Barbas H. The prefrontal cortex, pathological anxiety, and anxiety disorders. *Neuropsychopharmacology*. 2022;47(1):260-275.

doi: 10.1038/s41386-021-01109-z

20. Lopez KC, Kandala S, Marek S, Barch DM. Development of network topology and functional connectivity of the prefrontal cortex. *Cereb Cortex*. 2020;30(4):2489-2505.

doi: 10.1093/cercor/bhz255

21. Friedman NP, Robbins TW. The role of prefrontal cortex in cognitive control and executive function. *Neuropsychopharmacology*. 2022;47(1):72-89.

doi: 10.1038/s41386-021-01132-0

22. Kondo HM, Terashima H, Kihara K, Kochiyama T, Shimada Y, Kawahara JI. Prefrontal GABA and glutamate-glutamine levels affect sustained attention. *Cereb Cortex*. 2023;33(19):10441-10452.

doi: 10.1093/cercor/bhad294

23. Yan Z, Rein B. Mechanisms of synaptic transmission dysregulation in the prefrontal cortex: Pathophysiological implications. *Mol Psychiatry*. 2022;27(1):445-465.

doi: 10.1038/s41380-021-01092-3

24. Hiser J, Koenigs M. The multifaceted role of ventromedial prefrontal cortex in emotion, decision-making, social cognition, and psychopathology. *Biol Psychiatry*. 2018;83(8):638-647.

doi: 10.1016/j.biopsych.2017.10.030

25. Anastasiades PG, Carter AG. Circuit organization of the rodent medial prefrontal cortex. *Trends Neurosci*. 2021;44(7):550-563.

doi: 10.1016/j.tins.2021.03.006

26. Kolk SM, Rakic P. Development of prefrontal cortex. *Neuropsychopharmacology*. 2022;47(1):41-57.

doi: 10.1038/s41386-021-01137-9

27. Ahuja A, Yusif Rodriguez N. Is the dorsolateral prefrontal cortex actually several different brain areas? *J Neurosci*. 2022;42(33):6310-6312.

doi: 10.1523/JNEUROSCI.0848-22.2022

28. Manelis A, Huppert TJ, Rodgers E, Swartz HA, Phillips ML. The role of the right prefrontal cortex in recognition of facial emotional expressions in depressed individuals: fNIRS study. *J Affect Disord*. 2019;258:151-158.

doi: 10.1016/j.jad.2019.08.006

29. Doebel S. Rethinking executive function and its development. *Perspect Psychol Sci*. 2020;15(4):942-956.

doi: 10.1177/1745691620904771

30. Curtin A, Tong S, Sun J, Wang J, Onaral B, Ayaz H. A systematic review of integrated functional near-infrared spectroscopy (fNIRS) and transcranial magnetic stimulation (TMS) studies. *Front Neurosci*. 2019;13:84.

doi: 10.3389/fnins.2019.00084

31. Su WC, Colacot R, Ahmed N, Nguyen T, George T, Gandjbakhche A. The use of functional near-infrared spectroscopy in tracking neurodevelopmental trajectories in infants and children with or without developmental disorders: A systematic review. *Front Psychiatry*. 2023;14:1210000.

doi: 10.3389/fpsyt.2023.1210000

32. Pinti P, Tachtsidis I, Hamilton A, *et al*. The present and future use of functional near-infrared spectroscopy (fNIRS) for cognitive neuroscience. *Ann N Y Acad Sci*. 2020;1464(1):5-29.

doi: 10.1111/nyas.13948

33. Quaresima V, Ferrari M. A mini-review on functional near-infrared spectroscopy (fNIRS): Where do we stand, and where should we go? *Photonics*. 2019;6(3):87.

doi: 10.3390/photonics6030087

34. Gao L, Lin Q, Tian D, Zhu S, Tai X. Advances and trends in the application of functional near-infrared spectroscopy for pediatric assessments: A bibliometric analysis. *Front Neurol*. 2024;15:1459214.

doi: 10.3389/fneur.2024.1459214

35. Bourguignon NJ, Bue SL, Guerrero-Mosquera C, Borragán G. Bimodal EEG-fNIRS in Neuroergonomics. Current evidence and prospects for future research. *Front Neuroergon*. 2022;3:934234.

doi: 10.3389/fnrgo.2022.934234

36. Zhang Y, Li L, Bian Y, *et al*. Theta-burst stimulation of TMS treatment for anxiety and depression: A FNIRS study. *J Affect Disord*. 2023;325:713-720.

doi: 10.1016/j.jad.2023.01.062

37. Jeong E, Seo M, Kim KS. Design of an fNIRS-EEG hybrid terminal for wearable BCI systems. *Rev Sci Instrum*. 2024;95(8):085001.

doi: 10.1063/5.0187070

38. Chen J, Xia Y, Zhou X, *et al*. fNIRS-EEG BCIs for motor rehabilitation: A review. *Bioengineering (Basel)*. 2023;10(12):1393.

doi: 10.3390/bioengineering10121393

39. Liu Z, Shore J, Wang M, Yuan F, Buss A, Zhao X. A systematic review on hybrid EEG/fNIRS in brain-computer interface. *Biomed Signal Proces*. 2021;68:102595.

doi: 10.1016/j.bspc.2021.102595

40. Zhao YN, Han PP, Zhang XY, Bi X. Applications of functional near-infrared spectroscopy (fNIRS) neuroimaging during rehabilitation following stroke: A review. *Med Sci Monit*. 2024;30:e943785.

doi: 10.12659/msm.943785

41. Peng C, Hou X. Applications of functional near-infrared spectroscopy (fNIRS) in neonates. *Neurosci Res*. 2021;170:18-23.

doi: 10.1016/j.neures.2020.11.003

42. Holmes M, Aalto D, Cummine J. Opening the dialogue: A preliminary exploration of hair color, hair cleanliness, light, and motion effects on fNIRS signal quality. *PLoS One*. 2024;19(5):e0304356.

doi: 10.1371/journal.pone.0304356

43. Pinti P, Scholkmann F, Hamilton A, Burgess P, Tachtsidis I. Current status and issues regarding pre-processing of fNIRS neuroimaging data: An Investigation of diverse signal filtering methods within a general linear model framework. *Front Hum Neurosci*. 2018;12:505.

doi: 10.3389/fnhum.2018.00505

44. Butler LK, Kiran S, Tager-Flusberg H. Functional near-infrared spectroscopy in the study of speech and language impairment across the life span: A systematic review. *Am J Speech Lang Pathol*. 2020;29(3):1674-1701.

doi: 10.1044/2020-ajslp-19-00050

45. Vural Keles O, Yildirim E. Depression affects working memory performance: A functional near infrared spectroscopy (fNIRS) study. *Psychiatry Res Neuroimaging*. 2023;329:111581.

doi: 10.1016/j.pscychresns.2022.111581

46. Girolamo T, Butler L, Canale R, Aslin RN, Eigsti IM. fNIRS studies of individuals with speech and language impairment underreport sociodemographics: A systematic review. *Neuropsychol Rev*. 2023;34:860-881.

doi: 10.1007/s11065-023-09618-y

47. Wang Z, Ren K, Li D, *et al*. Assessment of brain function in patients with cognitive impairment based on fNIRS and gait analysis. *Front Aging Neurosci*. 2022;14:799732.

doi: 10.3389/fnagi.2022.799732

48. Pizzagalli DA, Roberts AC. Prefrontal cortex and depression. *Neuropsychopharmacology*. 2022;47(1):225-246.

doi: 10.1038/s41386-021-01101-7

49. Yeung MK, Lee TL, Chan AS. Negative mood is associated with decreased prefrontal cortex functioning during working memory in young adults. *Psychophysiology*. 2021;58(6):e13802.

doi: 10.1111/psyp.13802

50. Li G, Ma K, Rossbach K, *et al*. Cortical activation for adolescent-onset minor depression and major depressive disorder: An fNIRS study. *Ann Gen Psychiatry*. 2024;23(1):17.

doi: 10.1186/s12991-024-00500-6

51. Lim S, Park JH. Prefrontal cortex activation and working memory performance in individuals with non-clinical depression: Insights from fNIRS. *Acta Psychol (Amst)*. 2024;251:104571.

doi: 10.1016/j.actpsy.2024.104571

52. Tseng HJ, Lu CF, Jeng JS, *et al*. Frontal asymmetry as a core feature of major depression: A functional near-infrared spectroscopy study. *J Psychiatry Neurosci*. 2022;47(3):E186-E193.

doi: 10.1503/jpn.210131

53. Fan H, Li Q, Du Y, *et al*. Relationship of prefrontal cortex activity with anhedonia and cognitive function in major depressive disorder: An fNIRS study. *Front Psychiatry*. 2024;15:1428425.

doi: 10.3389/fpsyt.2024.1428425

54. Wu H, Li T, Peng C, *et al*. The right prefrontal cortex (PFC) can distinguish anxious depression from non-anxious depression: A promising functional near infrared spectroscopy study (fNIRS). *J Affect Disord*. 2022;317:319-328.

doi: 10.1016/j.jad.2022.08.024

55. Papasideris M, Ayaz H, Hall PA. Medial prefrontal brain activity correlates with emerging symptoms of anxiety and depression in late adolescence: A fNIRS study. *Dev Psychobiol*. 2021;63(7):e22199.

doi: 10.1002/dev.22199

56. Xu H, Wang Y, Wang YM, *et al*. Insomniacs show greater prefrontal activation during verbal fluency task compared to non-insomniacs: A functional near-infrared spectroscopy investigation of depression in patients. *BMC Psychiatry*. 2023;23(1):217.

doi: 10.1186/s12888-023-04694-z

57. Zhang Y, Li B, Zhang L, *et al*. Prefrontal brain activity and self-injurious behavior in adolescents with major depressive disorder: A functional near-infrared spectroscopy (fNIRS) study. *J Psychiatr Res*. 2024;176:248-253.

doi: 10.1016/j.jpsychires.2024.06.001

58. Zhang Y, Zheng M, Zhu D, *et al*. Distinct prefrontal cortex alterations in confirmed and suspected depression individuals with different perceived stress during an emotional autobiographical memory task: One fNIRS investigation. *J Affect Disord*. 2025;370:217-228.

doi: 10.1016/j.jad.2024.10.089

59. Koike S, Sakakibara E, Satomura Y, *et al*. Shared functional impairment in the prefrontal cortex affects symptom severity across psychiatric disorders. *Psychol Med*. 2022;52(13):2661-2670.

doi: 10.1017/s0033291720004742

60. Yang T, Wang H, Dai H, *et al*. The fNIRS evaluation of frontal and temporal lobe cortical activation in Chinese first-

episode medication-naïve and recurrent depression during a verbal fluency task. *Front Psychiatry*. 2023;14:1132666.

doi: 10.3389/fpsyt.2023.1132666

61. Hughes H, Brady LJ, Schoonover KE. GABAergic dysfunction in postmortem dorsolateral prefrontal cortex: Implications for cognitive deficits in schizophrenia and affective disorders. *Front Cell Neurosci*. 2024;18:1440834.

doi: 10.3389/fncel.2024.1440834

62. Pu S, Nakagome K, Yamada T, *et al*. Social cognition and prefrontal hemodynamic responses during a working memory task in schizophrenia. *Sci Rep.* 2016;6:22500.

doi: 10.1038/srep22500

63. Kumar V, Nichenmetla S, Chhabra H, *et al*. Prefrontal cortex activation during working memory task in schizophrenia: A fNIRS study. *Asian J Psychiatr*. 2021;56:102507.

doi: 10.1016/j.ajp.2020.102507

64. Curtin A, Sun J, Zhao Q, *et al*. Visuospatial task-related prefrontal activity is correlated with negative symptoms in schizophrenia. *Sci Rep.* 2019;9(1):9575.

doi: 10.1038/s41598-019-45893-7

65. Shinba T, Kariya N, Matsuda S, Arai M, Itokawa M, Hoshi Y. Near-infrared time-resolved spectroscopy shows anterior prefrontal blood volume reduction in schizophrenia but not in major depressive disorder. *Sensors (Basel)*. 2022;22(4):1594.

doi: 10.3390/s22041594

66. Diao Y, Wang H, Wang X, *et al*. Discriminative analysis of schizophrenia and major depressive disorder using fNIRS. *J Affect Disord*. 2024;361:256-267.

doi: 10.1016/j.jad.2024.06.013

67. Ma CC, Lin YY, Chung YA, *et al*. The two-back task leads to activity in the left dorsolateral prefrontal cortex in schizophrenia patients with predominant negative symptoms: A fNIRS study and its implication for tDCS. *Exp Brain Res*. 2024;242(3):585-597.

doi: 10.1007/s00221-023-06769-5

68. Singh R, Zhang Y, Bhaskar D, *et al*. Deep multimodal representations and classification of first-episode psychosis via live face processing. *Front Psychiatry*. 2025;16:1518762.

doi: 10.3389/fpsyt.2025.1518762

69. Poikonen H, Duberg A, Eriksson M, *et al*. "InMotion"-mixed physical exercise program with creative movement as an intervention for adults with schizophrenia: Study protocol for a randomized controlled trial. *Front Hum Neurosci*. 2023;17:1192729.

doi: 10.3389/fnhum.2023.1192729

70. Khaksari K, Chen WL, Chanvanichtrakool M, Taylor A, Kotla R, Gropman AL. Applications of near-infrared spectroscopy in epilepsy, with a focus on mitochondrial disorders. *Neurotherapeutics*. 2024;21(1):e00323.

doi: 10.1016/j.neurot.2024.e00323

71. Kaga Y, Ohyama T, Goto Y, *et al*. Impairment of autonomic emotional response for executive function in children with ADHD: A multi-modal fNIRS and pupillometric study during the wisconsin card sorting test. *Brain Dev*. 2022;44(7):438-445.

doi: 10.1016/j.braindev.2022.03.007

72. Friedman LM, Eckrich SJ, Rapport MD, Bohil CJ, Calub C. Working and short-term memory in children with ADHD: An examination of prefrontal cortical functioning using functional near-infrared spectroscopy (fNIRS). *Child Neuropsychol*. 2024;30(3):462-485.

doi: 10.1080/09297049.2023.2213463

73. Li Y, Chen J, Zheng X, Liu J, Peng C, Liao Y. Functional near-infrared spectroscopy evidence of prefrontal regulation of cognitive flexibility in adults with ADHD. *J Atten Disord*. 2023;27(11):1196-1206.

doi: 10.1177/10870547231154902

74. Li Y, Chen J, Zheng X, *et al*. Cognitive deficit in adults with ADHD lies in the cognitive state disorder rather than the working memory deficit: A functional near-infrared spectroscopy study. *J Psychiatr Res*. 2022;154:332-340.

doi: 10.1016/j.jpsychires.2022.07.064

75. Husain SF, Chiang SK, Vasu AA, *et al*. Functional near-infrared spectroscopy of english-speaking adults with attention-deficit/hyperactivity disorder during a verbal fluency task. *J Atten Disord*. 2023;27(13):1448-1459.

doi: 10.1177/10870547231180111

76. Ortuno-Miro S, Molina-Rodriguez S, Belmonte C, Ibanez-Ballesteros J. Identifying ADHD boys by very-low frequency prefrontal fNIRS fluctuations during a rhythmic mental arithmetic task. *J Neural Eng*. 2023;20(3).

doi: 10.1088/1741-2552/acad2b

77. Yang X, Zeng Y, Jiao G, *et al*. A brief real-time fNIRS-informed neurofeedback training of the prefrontal cortex changes brain activity and connectivity during subsequent working memory challenge. *Prog Neuropsychopharmacol Biol Psychiatry*. 2024;132:110968.

doi: 10.1016/j.pnpbp.2024.110968

78. Lu H, Zhang Y, Qiu H, *et al*. A new perspective for evaluating the efficacy of tACS and tDCS in improving executive functions: A combined tES and fNIRS study. *Hum Brain Mapp*. 2024;45(1):e26559.

doi: 10.1002/hbm.26559

79. Zhuo L, Zhao X, Zhai Y, *et al*. Transcutaneous electrical acupoint stimulation for children with attention-deficit/hyperactivity disorder: A randomized clinical trial. *Transl*

Psychiatry. 2022;12(1):165.

doi: 10.1038/s41398-022-01914-0

80. Li Y, Ma S, Zhang X, Gao L. ASD and ADHD: Divergent activating patterns of prefrontal cortex in executive function tasks? *J Psychiatr Res*. 2024;172:187-196.

doi: 10.1016/j.jpsychires.2024.02.012

81. Han YMY, Chan MC, Chan MMY, Yeung MK, Chan AS. Effects of working memory load on frontal connectivity in children with autism spectrum disorder: A fNIRS study. *Sci Rep*. 2022;12(1):1522.

doi: 10.1038/s41598-022-05432-3

82. Chen L, Du B, Li K, *et al*. The effect of tDCS on inhibitory control and its transfer effect on sustained attention in children with autism spectrum disorder: An fNIRS study. *Brain Stimul*. 2024;17(3):594-606.

doi: 10.1016/j.brs.2024.04.019

83. Chen H, Liang Q, Wang B, Liu H, Dong G, Li K. Sports game intervention aids executive function enhancement in children with autism - an fNIRS study. *Neurosci Lett*. 2024;822:137647.

doi: 10.1016/j.neulet.2024.137647

84. Keles HO, Karakulak EZ, Hanoglu L, Omurtag A. Screening for alzheimer's disease using prefrontal resting-state functional near-infrared spectroscopy. *Front Hum Neurosci*. 2022;16:1061668.

doi: 10.3389/fnhum.2022.1061668

85. Zhang M, Qu Y, Li Q, *et al*. Correlation between prefrontal functional connectivity and the degree of cognitive impairment in alzheimer's disease: A functional near-infrared spectroscopy study. *J Alzheimers Dis*. 2024;98(4):1287-1300.

doi: 10.3233/JAD-230648

86. Lee TL, Guo L, Chan AS. fNIRS as a biomarker for individuals with subjective memory complaints and MCI. *Alzheimers Dement*. 2024;20:5170-5182.

doi: 10.1002/alz.13897

87. Baik JS, Ko MH, Ko SH, *et al*. Assessment of functional near-infrared spectroscopy by comparing prefrontal cortex activity: A cognitive impairment screening tool. *Alzheimer Dis Assoc Disord*. 2022;36(3):266-268.

doi: 10.1097/WAD.0000000000000475

88. Zhang C, Yang H, Fan CC, *et al*. Comparing multi-dimensional fNIRS features using bayesian optimization-based neural networks for mild cognitive impairment (MCI) detection. *IEEE Trans Neural Syst Rehabil Eng*. 2023;31:1019-1029.

doi: 10.1109/TNSRE.2023.3236007

89. Hou M, Mao X, Wei Y, *et al*. Pattern of prefrontal cortical activation and network revealed by task-based and resting-state fNIRS in Parkinson's disease's patients with overactive bladder symptoms. *Front Neurosci*. 2023;17:1142741.

doi: 10.3389/fnins.2023.1142741

90. Assad M, Galperin I, Giladi N, Mirelman A, Hausdorff JM, Maidan I. Disease severity and prefrontal cortex activation during obstacle negotiation among patients with Parkinson's disease: Is it all as expected? *Parkinsonism Relat Disord*. 2022;101:20-26.

doi: 10.1016/j.parkreldis.2022.06.006

91. Orcioli-Silva D, Vitorio R, Beretta VS, *et al*. Is cortical activation during walking different between parkinson's disease motor subtypes? *J Gerontol A Biol Sci Med Sci*. 2021;76(4):561-567.

doi: 10.1093/gerona/glaa174

92. Orcioli-Silva D, Vitorio R, Nobrega-Sousa P, *et al*. Levodopa facilitates prefrontal cortex activation during dual task walking in parkinson disease. *Neurorehabil Neural Repair*. 2020;34(7):589-599.

doi: 10.1177/1545968320924430