

近红外脑功能成像在儿童孤独症谱系障碍诊疗中的应用

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摘要: 孤独症谱系障碍(ASD)是一种神经发育障碍性疾病,其主要特征为社交障碍和重复刻板行为。近年来,近红外脑功能成像(fNIRS)作为一种非侵入性神经成像技术,因其运动耐受性与便携性,在 ASD 儿童的神经机制研究与临床干预中展现出显著潜力。本文旨在系统综述 fNIRS 在 ASD 儿童静息态、任务态及干预评估中的应用进展,重点归纳了 ASD 儿童存在功能连接减弱、人际神经同步性不足等特征性异常,并深入探讨当前方法学挑战与未来临床转化路径,以期为推动 fNIRS 成为 ASD 神经机制研究和精准医疗的工具提供参考。

关键词: 孤独症谱系障碍; 近红外脑功能成像; 静息态; 任务态; 儿童

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Application of functional near-infrared spectroscopy in the diagnosis and treatment of children with autism spectrum disorder

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Abstract: Autism spectrum disorder (ASD) is a neurodevelopmental disorder primarily characterized by social deficits and restricted, repetitive behaviors. In recent years, functional near-infrared spectroscopy (fNIRS), a non-invasive neuroimaging technique, has shown considerable potential in studying the neural mechanisms of ASD and evaluating clinical interventions because of its motion tolerance and portability. This review aims to systematically summarize the application of fNIRS in resting-state, task-state, and intervention assessments in children with ASD. Particular emphasis is placed on characteristic abnormalities in ASD, such as reduced functional connectivity and impaired interpersonal neural synchrony. Furthermore, the current methodological challenges and pathways for future clinical translation are discussed, aiming to provide a scientific reference for the promotion of fNIRS as a tool for investigating neural mechanisms and advancing precision medicine in ASD.

Keywords: autism spectrum disorder; functional near-infrared spectroscopy; resting-state; task-state; children

孤独症谱系障碍(autism spectrum disorder, ASD)是一种神经发育障碍性疾病,由 Kanner^[1]于 1943 年首次提出,其核心症状为社交障碍和重复刻板行为。据报道,过去几十年中 ASD 发病率显著上升。在美国,2022 年 8 岁儿童 ASD 发病率为 1/31^[2],2017—2023 年我国 14 岁以下儿童 ASD 患病率为 0.7%^[3],且以男性多见^[4]。ASD 病因尚未完全明确,目前主要认为是遗传与环境这两大因素交互作

用所致^[5]。ASD 的临床表现具有高度异质性,其诊断目前主要依赖于医生根据病史、体格检查、行为观察与标准化评估综合判断。近年来,脑成像技术作为客观指标在 ASD 儿童神经机制的探索应用方面发展迅速^[6-7]。常见脑成像技术主要包括磁共振(magnetic resonance imaging, MRI)、功能磁共振成像(functional magnetic resonance imaging, fMRI)、近红外脑功能成像(functional near-infrared

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spectroscopy, fNIRS)、脑电图 (electroencephalogram, EEG) 等。fNIRS 作为非侵入性的神经成像技术,在 ASD 儿童诊疗中的应用日益广泛。相较于既往 fNIRS 在 ASD 应用的研究综述局限于特定神经机制或分析技术(如脑功能连接、超扫描及机器学习等),本文首次将多种范式及干预评估的研究成果进行总结,对 ASD 儿童特征性脑功能异常做更全面的阐述,并对当前研究挑战及未来临床转化进行讨论,以期 fNIRS 在 ASD 儿童早期诊断和干预效果评估中的探索性应用提供参考。

1 近红外脑功能成像介绍

1.1 近红外脑功能成像原理 fNIRS 是一种利用近红外光谱技术探测大脑皮质功能激活的神经影像学方法^[8-9]。该技术基于神经血管耦合机制和近红外光在生物组织中的特殊光学特性,通过测量大脑皮层血氧依赖的血流动力学响应以间接反映神经活动。fNIRS 设备发射 600~900nm 波段的近红外光,具有较强的组织穿透能力,并可被氧合血红蛋白(oxygenated hemoglobin, HbO)和脱氧血红蛋白(deoxygenated hemoglobin, HbR)以不同程度吸收^[8, 10]。光子在大脑发生散射,部分经大脑皮层反射回头皮表面并被探测器接收。大脑完成任务时,神经元活动增强并引起局部能量代谢需求增加,进而触发血流动力学反应(血流、血容量及血氧水平变化),组织的光学特性随之产生变化。中枢神经系统活动开始后,局部脑区 HbO 浓度显著升高, HbR 浓度轻微下降或先短暂升高后下降,总血红蛋白(total-hemoglobin, HbT)浓度相应增加,反映了神经元活动增强的脑区血容量增加^[11]。通过光学测量方法监测上述分子的变化,并利用改良的比尔-朗伯法(Beer-Lambert Law)量化,实现非侵入性监测大脑神经活动。

1.2 近红外脑功能成像特点 与同样基于血流动力学原理工作的 fMRI 相比, fNIRS 检测范围虽然仅局限于大脑皮层,但具有较高的时间分辨率^[12],不易受运动伪影的影响,使其尤适用于学龄前儿童的研究^[13]。与 EEG 相比, fNIRS 具有更优的空间分辨率。此外, fNIRS 还具有便携、成本较低、允许一定身体活动等优势^[14],成为临床应用及科研的热点。近年来,随着高密度探头矩阵、短通道技术及空间配准的发展, fNIRS 在数据质量及覆盖范围均有提升。对于指令遵从性和自控能力较差的 ASD 儿童来说, fNIRS 具有明显适用性,因此 fNIRS 在 ASD 儿童诊疗中应用愈发广泛。

2 fNIRS 范式在 ASD 诊疗中的应用与研究现状

2.1 静息态 静息态(resting-state, RS)是指受试者在无特定任务、保持清醒但放松状态下的自发神经活动模式,能够反映大脑基础功能网络的动态特性。有一些 fNIRS 静息态研究揭示了 ASD 儿童大脑功能连接存在系统性异常,普遍表现为连接减弱的整体趋势^[15-16]。具体而言,这种异常既体现在大脑半球间(如双侧颞叶同步性降低)^[15, 17],也体现在连接距离上,即短程与长程功能连接均弱于典型发育儿童^[18]。值得注意的是, ASD 儿童静息态信号表现出更高的复杂性,尤其左颞叶,且与功能连接强度呈负相关^[19],这提示其神经活动可能更为随机、难以预测。此外,传统静息态采集需 5~10min,但针对儿童的研究已尝试缩短时间以提高可行性,为临床应用提供了可能^[16]。近年来,一些研究采用基于多层神经网络的方法分析 fNIRS 静息态数据^[20-21],例如使用卷积神经网络等深度学习模型对 ASD 儿童进行分类,其准确率均达 90% 及以上,初显其作为 ASD 辅助诊断工具的潜力。然而,这些模型普遍存在样本量小、缺乏独立验证集等问题,未充分考虑 ASD 的临床异质性,其广泛应用状况仍有待验证。

2.2 任务态

2.2.1 被动任务态 任务态指研究者给予被试外部刺激(如图片、声音等)或明确行为指令(如按键、判断等)以诱发特定大脑加工过程。被动观看任务虽无需主动反应,却能有效诱发 ASD 儿童在社交与情绪加工脑区的异常激活模式。研究表明,与典型发育儿童相比, ASD 儿童在观看叙事或动画刺激时,并非单纯的激活不足,而更可能表现为功能连接紊乱(如顶枕叶连接增强但网络效率降低)^[22-23]以及神经时间序列的随机化^[24],进而导致关键脑区信息整合和传递的缺陷。重要的是,这些异常的神经活动模式与儿童孤独症评定量表等的阳性结果显著相关^[22, 24],提示被动任务范式捕获的神经生理特征有望成为 ASD 的客观评估指标。

2.2.2 语言加工任务 fNIRS 研究进一步深化了对 ASD 儿童早期语言发展神经机制的理解。在语言发展进程方面,具有 ASD 高遗传风险的婴儿在 6 月龄时已表现出对母亲和陌生女性的社会性语音刺激的颞叶和额叶激活减少及连接减弱^[25],进一步证实神经功能异常是临床症状的基础。在语言处理机制方面,典型发育儿童对母语刺激表现出清晰的左脑优势,并随语言相关性降低而减弱,而 ASD 儿童则无此趋势,甚至对乱序语言表现出右半球响应增

强^[26],同时其对社交情境中语言线索的加工能力也较弱^[27]。ASD 语言偏侧化减少与语言发育迟缓相关^[28],提示大脑半球功能偏侧化的缺失或异常可能是 ASD 儿童语言障碍的核心机制。

2.2.3 执行功能任务 执行功能是指个体对其思想和行动进行有意识控制的一系列高级心理过程。执行功能缺陷,尤其是抑制控制和工作记忆方面的困难在 ASD 儿童中普遍存在。fNIRS 研究揭示了前额叶功能障碍可能是其背后的机制。总体而言,ASD 儿童在执行任务态时,常表现出一种“低效能的神经激活”模式:即前额叶整体激活水平增高^[29],但关键脑区(如右侧前额叶)的功能连接减少,且无法像典型发育儿童那样随任务负荷改变灵活调节其功能连接^[30]。特别值得注意的是,ASD 与注意缺陷多动障碍(attention deficit/hyperactivity disorder, ADHD)共病率较高,仅从单一维度机制区分较为困难^[29],这种抑制控制功能障碍可能与 ADHD 存在共享的神经机制,表现为右前额叶激活显著降低。这种前额叶激活与连接的解离,可能与 ASD 患者常见的刻板认知和行为密切相关。

2.2.4 社交认知任务 社交障碍是 ASD 的核心症状,fNIRS(尤其是超扫描技术)为揭示其神经机制提供了独特视角。大量研究发现,在执行共同注意等社交任务时,ASD 儿童前额叶和颞叶激活及功能连接显著降低^[31-32]。更为重要的是,在双人互动情境中,ASD 儿童与同伴之间的脑间同步性显著低于典型发育儿童^[33]。这不仅表明其大脑内部社交网络的功能异常,更揭示了其在与他人进行人际神经同步上存在根本困难,且这种困难与其 ASD 特质的严重程度相关。这些发现为 ASD 的社交神经网络功能障碍假说提供了直接证据,并提示其神经基础不仅在于个体内部社交脑区低激活,同时还存在互动情境中双脑系统人际神经同步能力不足。

3 fNIRS 在 ASD 干预效果评估中的应用

fNIRS 作为客观评估工具,已应用于监测多种干预(如运动游戏、绘画等)对 ASD 儿童脑功能得到了改善效果。尽管干预方案各异,但研究结果呈现出一致性,即有效的干预方案能够增强前额叶皮层等脑区功能。在感觉统合训练干预后,ASD 儿童在 fNIRS 监测下执行 Go/No-Go 任务(需要按键反应的任务)时,右侧额下回和额中回的较基线激活水平显著增高,提示其执行功能得到了改善^[34]。有研究发现,8 周运动游戏训练后,干预组在执行功能核心维度上表现出显著改善。fNIRS 监测显示干预后执

行功能任务中被试背外侧前额叶皮层等脑区 HbO 浓度显著升高,静息态前额叶内部短程功能连接增强^[35]。一项美术治疗干预的研究发现,干预后 ASD 儿童的绘画能力、情绪表达及认知行为技能均得到显著提升,且 fNIRS 静息态和绘画任务中背外侧前额叶皮层等脑区与视觉、运动及语言相关脑区之间功能连接增强^[36]。另有一项研究比较了 ASD 儿童在创意运动、一般运动和静坐游戏三种干预方式的前后脑功能。干预后 fNIRS 超扫描发现创意运动组在任务态中表现出最广泛的社会性激活增强,一般运动组次之,而静坐游戏组激活最弱^[37]。为 fNIRS 捕捉不同类型动作干预的差异化效应提供了初步证据。

综上,这些神经功能层面上的积极变化,往往同步伴有执行功能、情绪管理与社交技能等指标的改善,为干预效果评估提供了脑功能测试的方案和支持数据。

4 存在的问题及挑战

尽管 fNIRS 在 ASD 研究中展现出一定优势,仍面临部分问题及挑战。首先,现有研究样本量小、随机对照试验不足,结论的普适性与统计效力有限。其次,ASD 儿童常伴有依从性困难,易引入运动伪影和信号噪声,影响数据质量。同时,现有研究多聚焦于前额叶区域,脑区覆盖范围有限,未能系统探讨广泛神经网络机制。此外,现有研究间试验范式不统一、数据处理缺乏标准化,不同研究间可比性和可重复性降低。最后,fNIRS 在空间分辨率和脑区探测深度方面存在局限,难以全面评估深部脑区功能。

5 总结与展望

fNIRS 作为非侵入性脑功能成像工具,在揭示 ASD 儿童静息态连接异常、任务态功能失调及干预后神经可塑性方面取得进展,但仍面临方法学标准化、样本异质性等挑战。未来研究应通过大样本、多中心随机对照试验设计,进一步提升 fNIRS 研究结果的可靠性。还可通过脑影像及脑电技术(如 fMRI、EEG)弥补 fNIRS 在时空分辨率方面的局限。建立标准化的数据采集与处理流程,开放并共享数据库,将进一步推动方法学进步与提升研究质量,为全面阐释脑机制提供支持。此外,随着轻量化和可穿戴 fNIRS 设备的发展,fNIRS 技术有望在临床和家庭环境中实现实时监测与评估,为 ASD 的诊断与治疗提供更有力的技术支撑。

参考文献

- [1] Kanner L. Autistic disturbances of affective contact[J]. Acta

- Paedopsychiatr, 1968, 35(4): 100-136.
- [2] Shaw KA, Williams S, Patrick ME, et al. Prevalence and early identification of autism spectrum disorder among children aged 4 and 8 years-autism and developmental disabilities monitoring network, 16 sites, United States, 2022[J]. *MMWR Surveill Summ*, 2025, 74(2): 1-22.
 - [3] Jiang X, Chen X, Su J, et al. Prevalence of autism spectrum disorder in mainland China over the past 6 years: A systematic review and meta-analysis[J]. *BMC Psychiatry*, 2024, 24(1): 404.
 - [4] 姜桐桐, 李秀琼, 赵婷婷, 等. 孤独症谱系障碍中性别差异的研究进展[J]. *中国当代儿科杂志*, 2025, 27(4): 480-486. Jiang TT, Li XQ, Zhao TT, et al. Advances in research on gender differences in autism spectrum disorders[J]. *Chin J Contemp Pediatr*, 2025, 27(4): 480-486. (in Chinese)
 - [5] Lipinski RJ, Krauss RS. Gene-environment interactions in birth defects and developmental disorders[M]. Amsterdam: Elsevier, 2023.
 - [6] Yen C, Lin CL, Chiang MC. Exploring the frontiers of neuroimaging: A review of recent advances in understanding brain functioning and disorders [J]. *Life*, 2023, 13(7): 1472.
 - [7] Xu M, Calhoun V, Jiang R, et al. Brain imaging-based machine learning in autism spectrum disorder: Methods and applications[J]. *J Neurosci Methods*, 2021, 361: 109271.
 - [8] Li R, Yang D, Fang F, et al. Concurrent fNIRS and EEG for brain function investigation: A systematic, methodology-focused review[J]. *Sensors*, 2022, 22(15): 5865.
 - [9] Eastmond C, Subedi A, De S, et al. Deep learning in fNIRS: A review[J]. *Neurophotonics*, 2022, 9(4): 041411.
 - [10] Jöbsis FF. Noninvasive, infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters [J]. *Science*, 1977, 198(4323): 1264-1267.
 - [11] Xie L, Liu Y, Gao Y, et al. Functional Near-Infrared Spectroscopy in neurodegenerative disease: A review[J]. *Front Neurosci*, 2024, 18: 1469903.
 - [12] Zhu Y, Liu S, Zhang F, et al. Response inhibition in children with different subtypes/presentations of attention deficit hyperactivity disorder: A near-infrared spectroscopy study[J]. *Front Neurosci*, 2023, 17: 1119289.
 - [13] Conti E, Scaife E, Bosetti C, et al. Looking for "fNIRS signature" in autism spectrum: A systematic review starting from preschoolers [J]. *Front Neurosci*, 2022, 16: 785993.
 - [14] Klein F, Kohl SH, Lührs M, et al. From lab to life: Challenges and perspectives of fNIRS for haemodynamic-based neurofeedback in real-world environments[J]. *Phil Trans R Soc B*, 2024, 379(1915): 20230087.
 - [15] Sun W, Wu X, Zhang T, et al. Narrowband resting-state fNIRS functional connectivity in autism spectrum disorder [J]. *Front Hum Neurosci*, 2021, 15: 643410.
 - [16] Wu X, Lin F, Zhang T, et al. Acquisition time for functional near-infrared spectroscopy resting-state functional connectivity in assessing autism[J]. *Neurophotonics*, 2022, 9(4): 045007.
 - [17] Sun H, Lin F, Wu X, et al. Normalized mutual information of fNIRS signals as a measure for accessing typical and atypical brain activity [J]. *J Biophotonics*, 2023, 16(6): e202200369.
 - [18] Wu X, Lin F, Sun W, et al. Relationship between short-range and homotopic long-range resting state functional connectivity in temporal lobes in autism spectrum disorder [J]. *Brain Sci*, 2021, 11(11): 1467.
 - [19] Zhang T, Huang W, Wu X, et al. Altered complexity in resting-state fNIRS signal in autism: A multiscale entropy approach[J]. *Physiol Meas*, 2021, 42(8): 085004.
 - [20] Fan Z, Gao Z, Xu L, et al. Identification of autism spectrum disorder based on functional near-infrared spectroscopy using dynamic multi-attribute spatio-temporal graph neural network[J]. *Biomed Signal Process Control*, 2024, 94: 106364.
 - [21] Cai J, Zeng X, Li J. Classification of autism spectrum disorder using edge-weight enhanced graph attention network with multiple features of resting-state fNIRS signals[J]. *J Biophotonics*, 2025, 18(11): e202500138.
 - [22] Guo X, Xu C, Chen J, et al. Disrupted cognitive and affective empathy network interactions in autistic children viewing social animation[J]. *Soc Cogn Affect Neurosci*, 2024, 19(1): nsae028.
 - [23] Zhu C, Li H, Zhang L, et al. Functional near-infrared spectroscopy characteristics in children with autism spectrum disorder under animated video modeling therapy[J]. *Front Neurol*, 2025, 16: 1590185.
 - [24] Su C, Hu Y, Liu Y, et al. Linking connectivity dynamics to symptom severity and cognitive abilities in children with autism spectrum disorder: An fNIRS study[J]. *J Neurosci*, 2025, 45(44): e0161252025.
 - [25] Hoshino E, Hata M, Xu M, et al. Reward-related language processing of maternal speech in infants at different likelihood of ASD[J]. *Soc Cogn Affect Neurosci*, 2026, 21(1): nsaf125.
 - [26] Lai B, Yi A, Zhang F, et al. Atypical brain lateralization for speech processing at the sublexical level in autistic children revealed by fNIRS[J]. *Sci Rep*, 2024, 14: 2776.
 - [27] Pecukonis M, Gerson J, Gustafson-Alm H, et al. The neural bases of language processing during social and non-social contexts: A fNIRS study of autistic and neurotypical preschool-aged children[J]. *Mol Autism*, 2025, 16(1): 40.
 - [28] Peterson M, Prigge MBD, Floris DL, et al. Reduced lateralization of multiple functional brain networks in autistic males[J]. *J Neurodev Disord*, 2024, 16(1): 23.
 - [29] Li Y, Ma S, Zhang X, et al. ASD and ADHD: Divergent activating patterns of prefrontal cortex in executive function tasks? [J]. *J Psychiatr Res*, 2024, 172: 187-196.
 - [30] Han YMY, Chan MC, Chan MMY, et al. Effects of working memory load on frontal connectivity in children with autism spectrum disorder: A fNIRS study[J]. *Sci Rep*, 2022, 12: 1522.

- [31] Blanco B, Lloyd-Fox S, Begum-Ali J, et al. Cortical responses to social stimuli in infants at elevated likelihood of ASD and/or ADHD: A prospective cross-condition fNIRS study[J]. *Cortex*, 2023, 169: 18-34.
- [32] Piatti A, Van der Paelt S, Warreyn P, et al. Neural correlates of response to joint attention in 2-to-5-year-olds in relation to ASD and social-communicative abilities: An fNIRS and behavioral study [J]. *Autism Res*, 2024, 17 (6): 1106-1125.
- [33] Zhou X, Hong X, Wong PCM. Autistic traits modulate social synchronizations between school-aged children: Insights from three fNIRS hyperscanning experiments[J]. *Psychol Sci*, 2024, 35(8): 840-857.
- [34] Deng J, Lei T, Du X. Effects of sensory integration training on balance function and executive function in children with autism spectrum disorder: Evidence from footscan and fNIRS[J]. *Front Psychol*, 2023, 14: 1269462.
- [35] Chen H, Liang Q, Wang B, et al. Sports game intervention aids executive function enhancement in children with autism-An fNIRS study [J]. *Neurosci Lett*, 2024, 822: 137647.
- [36] Li G, Wei D, Lyu Z, et al. Prefrontal blood flow activity during drawing intervention in school-age children with autism: An fNIRS hyperscanning study[J]. *Brain Sci*, 2025, 15(5): 438.
- [37] Su WC, Tsuzuki D, Srinivasan S, et al. Neural effects of creative movement, general movement, and sedentary play interventions on interpersonal synchrony in children with autism spectrum disorder: A preliminary fNIRS study[J]. *Brain Sci*, 2025, 15(7): 683.

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- [15] 范娟,杜亚松,王立伟. Conners 父母用症状问卷的中国城市常模和信度研究[J]. *上海精神医学*, 2005, 17 (6): 321-323.
- Fan J, Du YS, Wang LW. The norm and reliability of the Conners Parent Symptom Questionnaire in Chinese urban children[J]. *Shanghai Archives of Psychiatry*, 2005, 17 (6): 321-323. (in Chinese)
- [16] 张厚粲. 韦氏儿童智力量表第四版(WISC-IV)中文版的修订[J]. *心理科学*, 2009, 32(5): 1177-1179.
- Zhang HC. The Revision of WISC-IV Chinese version[J]. *Psychological Science*, 2009, 32(5): 1177-1179. (in Chinese)
- [17] 陈美蓉,郭起浩,刘晓红. 正常老年人中 Stroop 色词干扰测验和连线测验稳定性的 2 年随访观察研究[J]. *诊断学理论与实践*, 2015, 14(5): 446-450.
- Chen MR, Guo QH, Liu XH. Study on stability of Stroop color word test and trail making test in normal elder people: A 2-year follow-up[J]. *J Diagn Concepts Pract*, 2015, 14(5): 446-450. (in Chinese)
- [18] Scarpina F, Tagini S. The Stroop Color and Word Test[J]. *Front Psychol*, 2017, 8: 557.
- [19] Hu LF, Zhong YY, Wang P, et al. White matter microstructural subgroups of children with ADHD: Similar clinical presentations and distinct neuropsychological profiles [J]. *J Psychiatr Res*, 2025, 183: 197-203.
- [20] O'Rourke SR, Bray AC, Anastopoulos AD. Anxiety symptoms and disorders in college students with ADHD[J]. *J Atten Disord*, 2020, 24(12): 1764-1774.
- [21] Liu TL, Yang P, Ko CH, et al. Association between ADHD symptoms and anxiety symptoms in Taiwanese adolescents [J]. *J Atten Disord*, 2014, 18(5): 447-455.
- [22] Tremblay S, Willcutt EG. Implications of co-occurrence between ADHD and anxiety in a community-based child sample[J]. *J Atten Disord*, 2025, 29(11): 911-923.
- [23] Jarrett MA. Attention-deficit/hyperactivity disorder symptoms, anxiety symptoms, and executive functioning in emerging adults [J]. *Psychol Assess*, 2016, 28 (2): 245-250.
- [24] Adamo N, Michelini G, Cheung CHM, et al. Does co-occurring anxiety modulate ADHD-related cognitive and neurophysiological impairments? [J]. *J Atten Disord*, 2021, 25(8): 1135-1145.
- [25] Ferrin M, Vance A. Differential effects of anxiety and depressive symptoms on working memory components in children and adolescents with ADHD combined type and ADHD inattentive type[J]. *Eur Child Adolesc Psychiatry*, 2014, 23(12): 1161-1173.
- [26] Ruf BM, Bessette KL, Pearlson GD, et al. Effect of trait anxiety on cognitive test performance in adolescents with and without attention-deficit/hyperactivity disorder[J]. *J Clin Exp Neuropsychol*, 2017, 39(5): 434-448.
- [27] 董超,张琳琳,钟蕴瑜,等. 利用剑桥自动化神经心理测验包探查注意缺陷多动障碍儿童多维度执行功能缺陷[J]. *中国儿童保健杂志*, 2024, 32(10): 1149-1154.
- Dong C, Zhang LL, Zhong YY, et al. Multidimensional executive function deficits in children with attention deficit hyperactivity disorder assessed by Cambridge Neuropsychological Test Automated Battery[J]. *Chin J Child Health Care*, 2024, 32(10): 1149-1154. (in Chinese)
- [28] Toussaint-Thorin M, Marchal F, Benkhaled O, et al. Executive functions of children with developmental dyspraxia: Assessment combining neuropsychological and ecological tests[J]. *Ann Phys Rehabil Med*, 2013, 56(4): 268-287.

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