Annals of Gastroenterology (2026) **39,** 174-183

Impact of pediatric gastrointestinal disorders on learning and cognitive development in schoolchildren

Artemis Katsiaflaka[a], Michael Doulberis[b,c], Maria Podaropoulou[d], Georgia Katsiaflaka[a], Xenia Anastassiou-Hadjicharalambous[a]

University of Nicosia, Cyprus; Zurich University Hospital, Switzerland; Kantonsspital Aarau, Switzerland; University Hospital Zurich, Switzerland

Abstract

Schoolchildren nowadays encounter multiple challenges within the teaching process. Learning disabilities (LD) are characterized as complex conditions that affect academic achievement and cognitive performance. LD are typically linked to neurodevelopmental and genetic factors. However, emerging evidence suggests they may be associated with gastrointestinal (GI) pathologies, including celiac disease, inflammatory bowel disease, irritable bowel syndrome, gastroesophageal reflux disease and *Helicobacter pylori* infection. The aforementioned GI disorders have been (indirectly) linked with a spectrum of outcomes, such as school functioning, attention regulation, fatigue, and broader cognitive and psychosocial development. The gut-brain axis enacts a crucial role in both cognition and behavior. Furthermore, functional GI disorders may also coexist with somatic symptom anxiety, including school refusal and hypervigilance to bodily sensations. A typical paradigm is emetophobia, an intense fear of vomit, which might result in food avoidance, social withdrawal or even academic disengagement. Moreover, iron and vitamin deficiencies, as manifestation of a malabsorption due to GI diseases, might impact concentration and memory. Additionally, sleep disturbances, chronic discomfort and psychological stress could deteriorate cognitive and educational functioning. This work reviews current evidence linking GI health to LD and related neurodevelopmental/psychological outcomes. Timely diagnosis and treatment, targeting both GI and psychological factors, might improve cognitive outcomes and learning potential in schoolchildren with LD. Future studies with longitudinal and interventional designs are warranted, in order to elucidate any causal relationships and to determine whether targeted treatment of GI disorders leads to objective improvement in learning and cognitive outcomes.

Keywords Schoolchildren, learning disabilities, gastrointestinal pathologies, irritable bowel syndrome, functional dyspepsia

Ann Gastroenterol 2026; 39 (2): 174-183

[a]University of Nicosia, Cyprus (Artemis Katsiaflaka, Georgia Katsiaflaka, Xenia Anastassiou-Hadjicharalambous); [b]Department of Gastroenterology and Hepatology, Department of Medicine, Zurich University Hospital, Switzerland (Michael Doulberis); [c]Division of Gastroenterology and Hepatology, Medical University Department, Kantonsspital Aarau, Switzerland (Michael Doulberis); [d]Department of Pediatric Psychiatry, University Hospital Zurich, Switzerland (Maria Podaropoulou)

Conflict of Interest: None

Correspondence to: Artemis Katsiaflaka, School of Humanities and Social Sciences Department of Social Sciences, Nicosia, Cyprus, 46 Makedonitissas Avenue, CY-2417 P.O. Box 24005, CY-1700 Nicosia, Cyprus, e-mail: artemis.katsiaflaka@gmail.com

Received 30 September 2025; accepted 6 January 2026; published online 12 February 2026

DOI: https://doi.org/10.20524/aog.2026.1044

Introduction

Schoolchildren are characterized by learning disabilities (LD) in a percentage reaching approximately 5% [1]. LD are widely known as a group of specific neurodevelopmental disorders (NDDs) that might influence the possession, organization, comprehension, retention or application of (non)verbal information [2,3]. Within the teaching process, this term is more specifically utilized to include "certain" LD, as defined in federal legislation mandating school districts to provide services to schoolchildren with special needs/disabilities [4].

The term LD is used here strictly for specific LD, whereas attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are discussed as NDDs, and anxiety-related phenomena (e.g., emetophobia) as psychological/psychiatric comorbidities that may indirectly influence school functioning, rather than constituting LD *per se*.

Apart from these acknowledged learning challenges, undiagnosed neuropsychological disorders in schoolchildren present a significant and complex challenge for teachers. Educators not infrequently confront pupils who struggle with cognitive/behavioral difficulties that remain unrecognized. This fact materially complicates the process of appropriate educational support [5].

Additionally, absenteeism due to medical conditions, particularly gastrointestinal (GI) symptoms, is a "real-life" problem in the school setting that has to be acknowledged. In this regard, emerging research highlights a direct connection between the GI system and the central nervous system (CNS), commonly referred to as the gut-brain axis [6]. This bidirectional communication pathway and crosstalk (Fig. 1) have been implicated in various NDDs and neuropsychiatric pathologies, suggesting that GI health might play a pivotal role in cognitive and behavioral outcomes among children with LD/school-functioning challenges, as well as in those with concurrent neuropsychological disorders [7,8].

Therefore, the aim of the current narrative review was to illuminate the gap and offer a "state of the art" update on the available scientific evidence supporting this association.

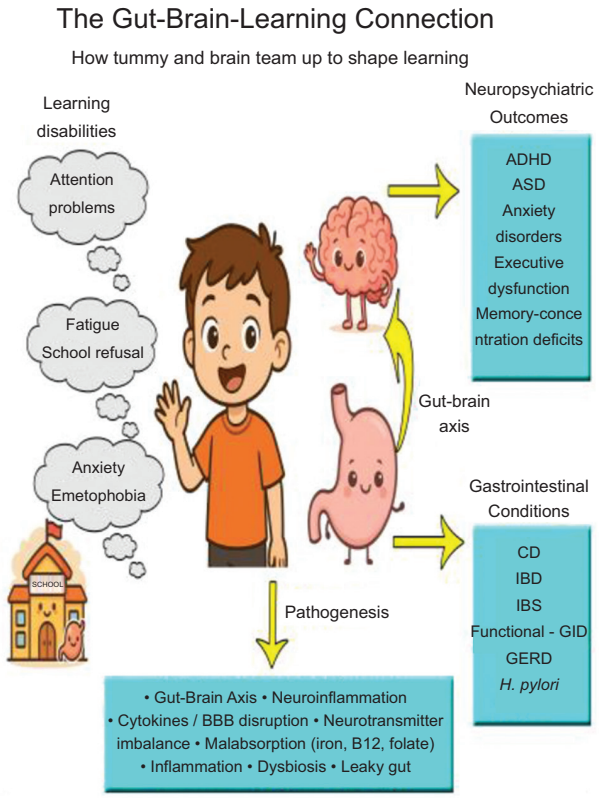

Figure 1 The gut-brain-learning connection. Conceptual illustration depicting the bidirectional interaction between gastrointestinal disorders and neuropsychiatric manifestations that may influence learning performance in school-aged children via the gut-brain axis
ADHD, attention-deficit/hyperactivity disorder; ASD, autism spectrum disorder; BBB, blood-brain barrier; CD, celiac disease; GERD, gastroesophageal reflux disease; IBD, inflammatory bowel disease; IBS, irritable bowel syndrome; GID, gastrointestinal disease

Nevertheless, it has to be emphasized that evidence remains largely observational, and significant gaps exist regarding causality, standardized cognitive outcomes and the impact of GI-targeted interventions on LD.

Methods

The present work is a narrative review that summarizes current evidence regarding the relationship between LD and GI disorders in schoolchildren. The literature search was conducted using PubMed/MEDLINE and Scopus databases, covering publications up to August 2025. Search terms included combinations of "learning disabilities," "neurodevelopmental disorders," "gut-brain axis," "gastrointestinal diseases," "celiac disease," "inflammatory bowel disease," "irritable bowel syndrome," "gastroesophageal reflux disease," "*Helicobacter pylori*," "microbiota," "children," and "adolescents." Priority was given to peer-reviewed studies, such as systematic reviews, meta-analyses and original articles focusing on pediatric populations, as well as key adult studies when pediatric data were limited. Article selection was based on relevance to the review's scope and mechanistic plausibility rather than formal systematic criteria.

LD in schoolchildren

LD in schoolchildren are neurodevelopmental conditions that impact the ability to process and utilize information in specific academic environments and contexts. Unlike intellectual disabilities, LD do not affect overall intelligence, but result in specific deficits in reading, writing and mathematics. The most representative types include dyslexia, dysgraphia, dyscalculia and nonverbal learning disability. It should be noted that LD may frequently coexist with NDDs, such as ASD and ADHD, but such entities are distinct conditions and are referred to separately throughout the manuscript [9,10].

These challenges can significantly influence the academic performance and self-esteem of affected schoolchildren, a fact that justifies the importance of timely diagnosis and treatment/intervention [1]. These disorders are characterized by a discrepancy between intellectual potential and academic achievement, and are typically identified during the early school years, when formal learning demands increase. Neurobiological evidence supports atypical neural activation and connectivity patterns in brain networks involved in language, executive functioning and academic skills [11,12].

The causes of LD are multifactorial, involving genetic, neurological and environmental influences. Family studies suggest a hereditary component, particularly in dyslexia, whereas brain imaging research highlights atypical neural activity in regions related to learning [9,10]. Prenatal exposure to toxins, poor nutrition and premature birth can also elevate the risk of LD. While LD are primarily neurodevelopmental in origin, emerging research suggests that gut-brain axis-related mechanisms, including chronic inflammation and microbiota

alterations, may influence cognitive development and school functioning; however, evidence for a direct causal role in LD remains limited and largely associative [6].

Schoolchildren with LD often struggle academically and socially, experiencing frustration, low self-esteem, and difficulty developing peer relationships. Anxiety and behavioral issues can develop as a result of repeated challenges in the classroom. Educators and healthcare professionals advocate for individualized education plans, multisensory learning approaches and assistive technology to support affected students [4].

Psychological support, such as cognitive-behavioral therapy, can help manage associated emotional difficulties. Advancements in neuroscience and education continue to provide new insights into LD, particularly in neuroplasticity and the gut-brain connection. Personalized learning technologies and early intervention strategies offer promising outcomes. With the right support, children with LD can achieve academic success and boost confidence in their abilities. Further research and interdisciplinary collaboration will be key in enhancing interventions and outcomes [13].

GI pathologies linked with neuropsychiatric diagnoses affecting learning performance

The relationship between GI diseases and educational outcomes in schoolchildren is increasingly recognized in the scientific society, with a plethora of pathologies acting synergistically to cause cognitive and behavioral impairments through certain mechanisms. Table 1 provides a structured overview of the discussed GI disorders along with comments about mechanistic aspects affecting learning and behavior, as well as clinical and educational recommendations.

Frequent medical check-ups, diagnostic procedures and emergency department admissions are not infrequently necessary for schoolchildren with chronic GI symptoms. Such absences may materially disrupt school continuity and daily rhythm, and may contribute synergistically to fatigue, anxiety, and ultimately to mental fragmentation. It is therefore reasonable to hypothesize that the school performance will be negatively influenced [14].

Celiac disease (CD) and its connection to LD

CD is a serious disease of autoimmune etiology, which affects genetically predisposed individuals after eating gluten (e.g., wheat). Pathophysiologically, it leads to small intestinal damage, and specifically villous atrophy, which results in malabsorption of nutrients such as folate and iron. Beyond its well-documented GI pathogenicity, CD is also acknowledged for its potential impact on cognitive functions and behavior, including LD. The prevalence of CD is approximately 1:100 for the general population. An even

Table 1 Gastrointestinal pathologies and their impact on learning disabilities, together with clinical and educational recommendations in schoolchildren

Gastrointestinal pathology	Mechanisms affecting learning	Cognitive and behavioral effects	Clinical/educational recommendation
Celiac disease	Chronic systemic inflammation, nutrient deficiencies (iron, folate, B12), gut-brain axis dysfunction	Attention deficits, executive dysfunction, 'brain fog', increased ADHD prevalence	Early diagnosis, lifelong GFD, school accommodations for fatigue/diet
Inflammatory bowel disease	Neuroinflammation, cytokine dysregulation (TNF), malabsorption of key nutrients, increased fatigue	Reduced school attendance, fatigue, impaired memory and processing speed, emotional distress	Fatigue monitoring, psychosocial support, flexible attendance policies, medical treatment of IBD and nutrient deficiency substitution
Irritable bowel syndrome & functional GI disorders	Gut-brain axis dysregulation, microbial imbalance, increased gut permeability, chronic stress	Deficits in attention, executive functioning, working memory, increased risk of ADHD and ASD	Cognitive-behavioral therapy, stress reduction programs, educational support for attention difficulties
Helicobacter pylori infection	Neuroinflammatory response, BBB permeability disruption, iron deficiency anemia, oxidative stress	Impaired concentration, memory deficits, cognitive decline, school absenteeism	Iron supplementation, symptom management, reduce absenteeism via health education, in selected cases eradication of *H. pylori*
Gastroesophageal reflux disease	Sleep disruption due to nocturnal symptoms, chronic stress, discomfort leading to distraction	Daytime fatigue, reduced attention span, impaired cognitive processing, increased behavioral issues	Sleep hygiene, pharmacological treatment, classroom seating considerations
Food sensitivities & dietary deficiencies	Micronutrient deficiencies (iron, omega-3, vitamin A & B12), restricted dietary diversity, neurodevelopmental delays	Cognitive impairment, heightened anxiety, behavioral dysregulation, academic underachievement	Individualized nutrition plans, monitoring for ARFID, school meal adjustments

Summary of the gastrointestinal pathologies discussed in the review, their proposed mechanisms affecting learning disabilities, cognitive and behavioral effects
ADHD, attention-deficit/hyperactivity disorder; ARFID, avoidant/restrictive food intake disorder; ASD, autism spectrum disorder; BBB, blood-brain barrier; CNS, central nervous system; EEN, exclusive enteral nutrition; EEG, electroencephalography; GFD, gluten-free diet; GI, gastrointestinal; IBD, inflammatory bowel disease; IQ, intelligence quotient; LD, learning disabilities; NDDs, neurodevelopmental disorders; SCFAs, short-chain fatty acids; TNF, tumor necrosis factor

higher incidence is reported in individuals with NDDs such as ASD and ADHD [15,16].

Untreated CD has been associated in the literature with cognitive complaints, often described as "brain fog". The latter includes difficulties in memory, concentration and executive functioning [17]. Titel *et al* reported that cognitive impairment, in a large cohort of diabetic children (type 1) with accompanying CD, improved significantly after establishment of a strict gluten-free diet (GFD). This suggests a potential association between gluten exposure and neurocognitive dysfunction [16]. From a pathophysiological perspective, chronic systemic inflammation, nutrient deficiencies (particularly iron, folate, and vitamin B12), and gut-brain axis impairment have been previously proposed as possible contributors to LD in CD patients [16].

Moreover, a higher prevalence of ADHD in individuals with CD has been reported compared to the general population. In particular, a meta-analysis found a significant association between CD and ADHD, with a pooled odds ratio of 1.39 [14], indicating that CD patients are more likely to exhibit attentional deficits [18]. Further relevant research suggests that adherence to a GFD may improve ADHD symptoms, (mostly inattention), thus suggesting a possible linkage between gluten exposure and cognitive and behavioral impairments [18].

The association between CD and ASD remains undetermined. Whereas some studies have reported a higher prevalence of CD among children with ASD, others have found no difference compared to the general population [19]. GI symptoms, (including those of CD), are common in ASD, and food sensitivities may exacerbate behavioral symptoms. However, routine screening for CD in the ASD setting is not generally recommended, apart from standard clinical indications and guidelines [19].

Overall, CD may adversely impact cognitive function and learning potential, especially if left untreated. The associations between CD, ADHD and ASD highlight the importance of considering gluten-related immune mechanisms in pediatric patients with neuropsychiatric manifestations. Given the potential for cognitive improvement on a GFD, early diagnosis and dietary management may enact a key role in mitigating LD, and therefore enhancing overall cognitive performance in affected individuals.

Irritable bowel syndrome (IBS) and other functional GI disorders: Impact on LD

IBS is a very common GI disease under the umbrella term of functional GI disorders (FGIDs). The hallmark of these disorders is the absence of structural damage. Their clinical manifestations extend beyond the GI tract, even impacting psychosocial process. As a clinical syndrome, IBS appears with cardinal symptoms recurrent abdominal discomfort or pain, bloating, and altered bowel habits. It is often linked to neuropsychiatric conditions, including ADHD and ASD. Emerging evidence suggests that individuals with IBS or other FGIDs may exhibit higher rates of cognitive difficulties, including deficits in attention, executive functioning and working memory [20].

An association has also been reported between ADHD-FGIDs, most notably IBS, functional dyspepsia and chronic constipation. In a large cohort study, young adults (17-35 years old) with ADHD showed a higher IBS prevalence than non-ADHD individuals (odds ratio 1.67, 95% confidence interval 1.56-1.80; $P<0.001$) [20]. Within the same cohort, the coexistence of FGIDs was associated with more frequent medical visits, reflecting the magnitude of the GI burden. It should be noted that the abovementioned findings indicate association rather than causation, and probably indicate overlapping neurobiological and gut-brain axis mechanisms [20].

Likewise, IBS has been reported at higher rates in pediatric populations with coexisting ASD, and has been associated with increased behavioral challenges and sensory sensitivities. ASD schoolchildren who experience recurrent GI symptoms, including chronic constipation and abdominal pain, are at greater risk for heightened stress responses, disrupted sleep and increased irritability, all of which may adversely affect their capacity to focus and engage in learning environments [21]. Additionally, anxiety disorders frequently coexist in children with IBS, further contributing to cognitive difficulties and school performance.

Recent clinical observations have described an overlap between FGIDs in children and anxiety-driven behaviors focused on bodily sensations and food ingestion, thus suggesting a close crosstalk between GI semiology and psychopathology [22,23].

A rather distressing manifestation is emetophobia (from the Greek word for "fear of vomiting"). Emetophobia in certain affected children may result in significant food avoidance, social withdrawal and reduced school performance. These symptoms are primarily anxiety-driven, rather than weight- or body-image-related. Such avoidance behaviors may lead to school absenteeism [24,25].

Therefore, the documented connection among FGIDs, LD and psychiatric comorbidities warrants a multidisciplinary approach to management. Addressing IBS in children with NDDs through dietary intervention, stress management policies and microbiome-targeted interventions may not only improve GI symptoms, but also support educational functioning. Nevertheless, it has to be stressed that the available evidence for direct effects on LD *per se* currently remains limited [15].

Future research should focus on elucidating mechanisms by which gut dysbiosis influences cognitive performance and psychiatric symptoms, paving the way for targeted therapeutic strategies.

Inflammatory bowel disease (IBD) and LD

IBD, whose principal forms are Crohn's disease and ulcerative colitis, is a chronic inflammatory, immune-mediated disease of the GI tract with relapsing character. The cardinal symptoms in children include abdominal pain, diarrhea, rectal

bleeding and weight loss, or even failure to thrive. Beyond its well-documented impact on digestion and immunity, emerging evidence suggests that IBD also affects cognitive function and learning abilities in children [26]. Disruptions in gut homeostasis, commonly seen in IBD, have been implicated in cognitive dysfunction, emotional disturbances and neuropsychiatric comorbidities, including depression, anxiety and ADHD [6].

Children and adolescents with IBD frequently experience academic difficulties due to a combination of disease activity, treatment side-effects and psychosocial factors. Studies have shown that children with IBD have reduced school attendance, concentration difficulties and lower academic performance compared to their healthy peers [26]. This may stem from both direct biological mechanisms, (e.g., chronic inflammation, malnutrition) and indirect factors (e.g., fatigue, pain, frequent hospital visits). A population-based study from Canada demonstrated that children with IBD had lower rates of school attendance and a greater risk of cognitive fatigue and executive dysfunction [26]. In Israel, children diagnosed with IBD were found to miss significantly more school days compared to their healthy peers, with absenteeism most pronounced among those with Crohn's disease (average of 24 days), followed by ulcerative colitis (21 days) and healthy controls (5.1 days) [26]. Furthermore, it has been suggested that the cascade of cytokine production within IBD may to contribute to brain processes. In particularly, tumor necrosis factor (TNF)-α, has been associated with neuroinflammation, with a potential negative impact on memory, attention and processing functions [6]. Pediatric IBD patients are more prone to emotional distress, anxiety and depressive disorders, all of which contribute synergistically to a deterioration of school performance [15].

Nutritional deficiencies are a major concern in IBD, and can significantly impact brain development and learning function. Iron, vitamin B12, folate and vitamin D deficiencies, commonly observed in IBD patients (both pediatric and adults), have been associated with impaired memory, attention deficits and executive dysfunction [26]. Pathogenetically, these deficiencies are a result of malabsorption of key nutrients due to intestinal inflammation, and surgical resections in severe cases, and may result in neurodevelopmental delays, particularly in schoolchildren with an early onset. Exclusive enteral nutrition is a core dietary intervention, often used as a first-line therapy in pediatric Crohn's disease, that has proved promising in reducing inflammation, while providing essential nutrients that support brain development. Nevertheless, persistent malnutrition in pediatric IBD, and consequently failure to thrive, are well-acknowledged factors for lower IQ scores and academic underachievement in schoolchildren with an aggressive disease course [26].

Children with IBD, as well as adolescents, exhibit a higher prevalence of psychiatric disorders, including ADHD, depression and anxiety, compared to the general population [6]. Results from large-scale registries and cohort studies have identified a bidirectional relationship between IBD and neuropsychiatric pathologies, suggesting that chronic inflammation and dysbiosis influence the CNS. In addition, genome-wide genetic association results have revealed common susceptibility loci between IBD and psychiatric diagnoses, particularly major depressive disorder and ADHD [6].

A relevant review of pediatric IBD reported that children with relapse were characterized by statistically significant higher rates of depression and anxiety compared to their counterparts in remission [27]. Notably, psychiatric comorbidities, and mainly depression and anxiety disorders, are more prevalent among IBD patients than the general population, and can materially compromise learning and school performance. A review article by Salducan *et al* summarized the current evidence regarding pediatric IBD patients, and concluded that schoolchildren are at an increased risk of associated anxiety, depression, panic disorder, phobias and dysthymias, a fact that may negatively affect the cognitive and educational outcomes of such children [28].

In summary, children with IBD are reported in the literature to have more frequent school absences and academic problems that extend beyond pure GI symptoms, primarily due to fatigue, depression and anxiety [29]. These psychological factors may contribute to LD. Therefore, clinical alertness, and early multidisciplinary intervention for comprehensive care that addresses both physical and mental health aspects of IBD are required [30].

Gastroesophageal reflux disease (GERD) and its impact on LD

GERD can indirectly, but significantly, influence the learning abilities of schoolchildren. The most chronic GERD symptoms include persistent heartburn and regurgitation, which not infrequently result in discomfort and retrosternal pain. This semiology is known to distract schoolchildren and adolescents from academic tasks, leading to reduced concentration, attention and classroom engagement, especially once symptoms are recurrent and refractory and are accompanied by prolonged school activities. Persistent discomfort may equally contribute to increased school absences, which may also compromise children's school performance [31,32].

Moreover, GERD has been indirectly associated in the literature with diverse NDDs. According to Dutt *et al*, children with cerebral palsy exhibit a high prevalence of sleep disturbances, and GERD is acknowledged as a silent and underdiagnosed contributing factor for sleep disruption in such a pediatric population [33]. Evidence has revealed that early-onset neurological impairment and abnormal electroencephalography results are significant risk factors for severe GERD in children [34]. Sleep disturbances represent an additional and clinically relevant concern, since GERD symptoms frequently disrupt sleep patterns, leading to daytime fatigue and diminished cognitive function. Adequate sleep is crucial for memory consolidation and learning; therefore, interrupted or fragmented sleep due to nocturnal reflux can impair a child's ability to process, retain and retrieve new information. Daytime somnolence and irritability may further aggravate attention difficulties and classroom behavior.

Several pediatric studies further support an indirect association between GERD and impaired school functioning through symptom burden, sleep disruption and reduced quality of life. In a Turkish pediatric quality-of-life study (n=93), children and adolescents with GERD reported significantly lower scores in school-related functioning domains, including concentration, energy levels and classroom participation, compared with healthy peers, with greater symptom severity correlating with increased functional impairment [32].

In a Japanese pediatric cohort of 336 children aged 4-12 years, Sakaguchi *et al* (2014) [31] found that GERD symptoms were significantly associated with sleep disturbances and behavioral problems, including attention deficits. Such symptoms are also linked to increased school absenteeism and classroom disengagement.

Pediatric quality-of-life studies have consistently shown a negative correlation between GERD symptom severity and school functioning. For example, Acierno *et al* (2010) developed a GERD-specific quality-of-life tool and found that children (n=19) with moderate-to-severe symptoms reported difficulties with concentration and classroom engagement [35].

The joint clinical practice guidelines of the North American and European Societies for Pediatric Gastroenterology emphasize that sleep disturbance and daytime fatigue are common extra-esophageal manifestations of GERD in children, and may contribute to impaired daytime cognitive performance and reduced school engagement [36]. Furthermore, studies examining children with chronic medical conditions, including GI disorders, demonstrate greater school absenteeism, reduced academic engagement and difficulties in sustained attention, underscoring the educational impact of the chronic symptom burden, even in the absence of direct cognitive pathology [14].

Addressing GERD in schoolchildren is therefore essential to mitigate its potential impact on learning and cognitive performance. Effective management may include lifestyle modifications, pharmacological treatments and, in selected cases, surgical interventions. Timely symptom control may improve comfort, sleep quality and functional school participation, thereby supporting overall cognitive functioning and educational outcomes [37].

Food sensitivities and dietary deficiencies in neuropsychiatric disorders

Food sensitivities and dietary deficiencies are well-acknowledged causes that significantly influence cognitive performance and school functioning in children, particularly those with NDDs. Neuropsychiatric disorders, such as ADHD and ASD, display selective eating patterns, leading to inadequate intake of essential nutrients. This nutritional imbalance can deteriorate cognitive and hence academic performance. In this respect, Liu *et al* reviewed the current evidence regarding the neurological and epigenetic impact of nutritional deficiencies on psychopathology, and deduced that deficiencies in iron and essential fatty acids have been linked to impaired neurological development, adversely affecting learning and cognition [38].

Moreover, certain food sensitivities may directly interfere with behavioral and learning processes. In particularly, schoolchildren with developmental disorders are more likely to have self-reported allergies, such as (cow) milk and egg allergies, which can contribute to developmental delays. Addressing these dietary issues through healthcare and nutrition providers with early interventions is important to support the cognitive and academic development of schoolchildren with LD [39].

Sensory sensitivities are common in schoolchildren with ASD, and they may contribute to avoidant/restrictive food intake disorder (ARFID), a diagnosis that also has the hallmark of extreme food selectivity and nutritional deficiencies, occasionally severe, including vitamin A and B12 deficiencies, which are crucial for brain development and vision. A recent review article by Schimansky *et al* reported cases of nutritional blindness in children with ARFID. The prevalence is even greater in schoolchildren with ASD, and a late diagnosis may render the blindness irreversible. This fact highlights the significance of early diagnosis and a multidisciplinary management approach [40].

The paramount role of balanced nutrition in brain development exceeds macronutrient intake. Grajek *et al*, in a review article, summarized the relevant evidence, and reported that high fat and sugar diets negatively affect brain function, increasing the risk of neuropsychiatric disorders. Contrariwise, plant-based diets, healthy fats of vegetable origin, and lean proteins, have been associated with improved mental health outcomes. Notably, randomized dietary intervention trials, including landmark ones like SMILES and HELFIMED, demonstrated that improving overall diet quality through Mediterranean-style dietary patterns can positively influence neurocognitive outcomes [41].

Moreover, further studies from pediatric populations suggest that specific additives, mainly artificial food colorings and preservatives, can worsen hyperactivity and inattention symptoms, which may negatively influence academic performance and focus [42,43]. Notably, in a relevant British double-blinded, placebo-controlled crossover trial involving 153 preschoolers (3-year-olds) and 144 school-aged children (8-9 years), consumption of artificial food colorings and the preservative sodium benzoate were associated with increased hyperactivity, as measured by behavioral ratings and attention tests. The aforementioned reports strengthen a possible link between dietary additives and adverse behavioral effects in children from the general population [43]. Furthermore, restricted elimination diets targeting, common allergens like gluten and dairy, have been shown to improve behavioral symptoms in distinct subgroups of children diagnosed with ADHD and specific LD, implying that systemic inflammation triggered by food intolerance may directly have an impact on cognitive and behavioral functions [44,45].

Taken together, both food sensitivities and dietary deficiencies are crucial in the management of schoolchildren with LD. A multidisciplinary approach involving healthcare providers, nutritionists, educators and families is advised in order to develop and implement effective dietary interventions aiming at the possible improvement of behavioral, cognitive and overall performance.

The role of gut microbiota dysbiosis in LD

The crosstalk between gut microbiota and the CNS has attracted global interest in the last decades. In particular, to what extent the (non)commensal intestinal flora shapes neurodevelopment and impacts on the LD of schoolchildren is a cutting-edge interdisciplinary topic. Gut microbiota dysbiosis, defined simply as an imbalance in the microbial community within the GI tract, has been repeatedly hypothesized in various NDDs, potentially influencing cognitive functions and academic performance [13]. It should be noted, however, that most available evidence is observational and does not suffice to prove causality between microbiota alterations and LD.

These associations are thought to be mediated through the aforementioned microbiota-gut-brain axis [20]. Suggested interconnected pathways include the following. First, the immune pathway, whereby gut microbiota modulate immune signaling through cytokine production; dysbiosis may promote systemic and neuroinflammation, processes implicated in NDDs and cognitive dysfunction [13]. Second, the neuronal pathway involves signaling through the autonomous enteric nervous system (mainly vagus nerve), allowing microbial metabolites to influence brain activity and behavior. Third, the endocrine and metabolic pathway includes microbiota-driven regulation of neuroactive compounds, such as serotonin and dopamine, which are directly involved in attention, mood regulation and learning processes. Specific gut microbial taxa are also involved in tryptophan metabolism and dopamine precursor availability, modulating neuroendocrine and CNS function [13].

GI symptoms frequently coexist in children with ASD and ADHD, and are often accompanied by gut microbiota alterations, but this overlapping probably reflects shared biological and psychosocial vulnerabilities, rather than a unidirectional causal pathway.

Several biologically plausible mechanisms have been proposed for how dysbiosis may contribute to LD. Neuroinflammation represents a key pathway, as microbial imbalance may increase gut permeability, allowing translocation of inflammatory mediators such as lipopolysaccharides (LPS) into the systemic circulation. These factors can compromise blood-brain barrier (BBB) integrity and promote neuroinflammatory cascades affecting cognition [46]. Additionally, altered microbial synthesis of neurotransmitters and reduced production of short-chain fatty acids—important modulators of synaptic plasticity—may further hamper learning-related neural processes [13].

Recognition of the role of gut microbiota in neurodevelopment and neuroplasticity opens potential avenues for supportive and preventive strategies, rather than established therapeutic interventions. Current evidence does not support routine probiotic or prebiotic supplementation to improve learning outcomes in schoolchildren. Instead, the literature emphasizes the importance of an overall healthy lifestyle—such as balanced nutrition that supports microbiome diversity, regular physical activity and avoidance of sedentary behavior—which may contribute to gut and brain health [13]. Microbiome-targeted interventions in this context remain experimental and should be interpreted cautiously in selected populations and cases.

Early-life nutrition and maternal dietary patterns play a critical role in shaping gut microbiota development and immune programming, with potential long-term implications for neurodevelopment and cognitive function. The establishment of the gut microbiome begins during pregnancy, and continues dynamically through early infancy and childhood, influenced by maternal diet and early nutritional exposures, which interact with gut-brain signaling pathways related to cognition and behavior [47]. Adherence of mothers in gestation to healthy dietary habits—particularly Mediterranean-style diets rich in dietary fiber, polyphenols and unsaturated fats (e.g., omega-3)—has been repeatedly linked to more favorable gut microbiota profiles and to better neurodevelopmental and immunological maturation of the newborn [48].

Although direct evidence linking early-life nutritional exposures to later LD remains rather limited, these factors represent biologically plausible contributors to cognitive and learning processes via microbiome-mediated mechanisms. Therefore, current evidence is largely associative, and prospective pediatric studies are warranted to clarify causality and determine whether early nutritional interventions result in objective benefits in learning and academic performance.

Helicobacter pylori (H. pylori) infection and LD in schoolchildren

H. pylori is a gram-negative, spiral-shaped bacterium that primarily colonizes the human stomach and belongs to the most prevalent infections globally. Its prevalence exceeds 50% of the Earth's population, with higher rates observed in patients/children from lower socioeconomic backgrounds. *H. pylori* has a well substantiated role in gastritis, peptic ulcer disease and gastric malignancies, while it has also been implicated in systemic conditions, such as metabolic syndrome, as well as cardiovascular and neurodegenerative or neuroinflammatory disorders [49-51].

H. pylori induces a chronic inflammatory state characterized by elevated levels of proinflammatory cytokines, such as TNF-α and interleukin-6, as well as oxidative stress, both of which contribute to cognitive decline. Moreover, *H. pylori* infection is also known to alter gut permeability, permitting bacterial compounds such LPS and other bacterial metabolites to translocate and enter the systemic circulation. The latter can compromise BBB integrity and has been implicated in neuroinflammatory processes affecting cognition and learning [52,53].

Furthermore, schoolchildren with *H. pylori* infection often experience symptoms such as abdominal pain, and laboratory findings such as iron deficiency anemia, which contribute to fatigue, irritability and decreased concentration [54,55]. As an impact, a schoolchild's ability to engage fully in the learning process is restricted, thereby possibly contributing to academic underachievement and LD. Moreover, *H. pylori*-

associated iron deficiency anemia is known to impair cognitive development and function, which is critical during the formative years of schooling [55]. *H. pylori* infection has been also linked to decreased levels of essential nutrients, including iron and vitamin B12, which are vital for optimal brain function [54,55]. In children, this can manifest as difficulties in attention, memory and overall academic performance, further compounding the challenges faced by those with LD. Additionally, the psychosocial impact of chronic illness, including the stigma associated with GI symptoms, can ultimately lead to social withdrawal and decreased self-esteem, thereby further exacerbating LD [56].

In a pedagogical context, educators and healthcare providers must recognize the potential impact of *H. pylori* infection on learning and development. Early identification and treatment of *H. pylori* infection in symptomatic schoolchildren could mitigate its adverse effects on academic performance and overall well-being. Schools should consider implementing health screening and educational programs to raise awareness about the implications of GI health on learning outcomes. By addressing these significant health issues, teachers can offer a more supportive environment that fosters the academic success of all students, particularly those at risk of LD due to chronic health conditions like *H. pylori* infection [56,57]. Nevertheless, it has to be acknowledged that the current evidence is very limited regarding *H. pylori* infection, and direct educational outcomes and further recommendations should be considered with caution.

Concluding remarks

It has been demonstrated that GI diseases such as celiac disease, IBD/IBS, GERD and *H. pylori* infection may negatively impact performance in schoolchildren via several pathways: disrupting nutrient absorption, causing chronic inflammation, and modifying gut-brain signaling. The abovementioned mechanisms may impair the attention, memory and executive functioning of schoolchildren. Fatigue, sleep disruption and chronic discomfort further interfere with and lessen academic performance and school attendance.

Additionally, psychosocial symptoms—including anxiety, social withdrawal, and low self-esteem—frequently coexist, especially in children diagnosed with ADHD or ASD. Functional GI disorders may also manifest somatic symptoms such as anxiety, and consequently school avoidance, as discussed in conditions like emetophobia.

A multidisciplinary approach is highly endorsed, combining pediatric GI care, psychological support and school-based accommodations. Early identification of GI contributors to LD can guide targeted interventions, such as treatment of the underlying disease as well as tailored educational support.

Insight into the role of GI health in cognitive development will definitively contribute to early recognition and intervention, improving outcomes for schoolchildren with LD. Future research should prioritize prospective, longitudinal pediatric cohorts and intervention studies integrating GI, neurocognitive and educational outcomes. Such approaches are essential if we are to move from associative evidence toward clinically actionable prevention and management strategies.

Acknowledgments

During manuscript preparation, Scholar of ChatGPT was used before submission solely for language editing and stylistic refinement. The authors take full responsibility for the scientific content, interpretation and conclusions.

References

1. Lagae L. Learning disabilities: definitions, epidemiology, diagnosis, and intervention strategies. *Pediatr Clin North Am* 2008;**55**: 1259-1268, vii.
2. Aslam SP, Carugno P. Learning Disorder. 2025 Dec 13. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan–.
3. Fletcher JM Lyon GR, Fuchs LS, Barnes MA. Learning disabilities: From identification to intervention. New York: Guilford Press; 2019.
4. Telzrow CF. Role of the school in serving children with learning disabilities. *Semin Neurol* 1991;**11**:50-56.
5. Loades ME, Mastroyannopoulou K. Teachers' recognition of children's mental health problems. *Child Adolesc Ment Health* 2010;**15**:150-156.
6. Nakhal MM, Yassin LK, Alyaqoubi R, et al. The microbiota-gut-brain axis and neurological disorders: a comprehensive review. *Life (Basel)* 2024;**14**:1234.
7. Laue HE, Coker MO, Madan JC. The developing microbiome from birth to 3 years: the gut-brain axis and neurodevelopmental outcomes. *Front Pediatr* 2022;**10**:815885.
8. McElhanon BO, McCracken C, Karpen S, Sharp WG. Gastrointestinal symptoms in autism spectrum disorder: a meta-analysis. *Pediatrics* 2014;**133**:872-883.
9. Brimo K, Dinkler L, Gillberg C, Lichtenstein P, Lundström S, Åsberg Johnels J. The co-occurrence of neurodevelopmental problems in dyslexia. *Dyslexia* 2021;**27**:277-293.
10. Moody S. Dyslexia, dyspraxia, and ADHD in adults: what you need to know. *Br J Gen Pract* 2014;**64**:252.
11. Peterson RL, Pennington BF. Developmental dyslexia. *Lancet* 2012;**379**:1997-2007.
12. Lyon GR, Shaywitz SE, Shaywitz BA. A definition of dyslexia. *Ann Dyslexia* 2003;**53**:1-14.
13. Wang Q, Yang Q, Liu X. The microbiota-gut-brain axis and neurodevelopmental disorders. *Protein Cell* 2023;**14**:762-775.
14. Shaw SR, McCabe PC. Hospital-to-school transition for children with chronic illness: meeting the new challenges of an evolving health care system. *Psychol Sch* 2007;**45**:74-87.
15. Al-Beltagi M, Saeed NK, Bediwy AS, Elbeltagi R, Alhawamdeh R. Role of gastrointestinal health in managing children with autism spectrum disorder. *World J Clin Pediatr* 2023;**12**:171-196.
16. Tittel SR, Dunstheimer D, Hilgard D, et al; DPV Initiative. Coeliac disease is associated with depression in children and young adults with type 1 diabetes: results from a multicentre diabetes registry.

Acta Diabetol 2021;**58**:623-631.
17. Gaur S. The association between ADHD and Celiac Disease in Children. *Children (Basel)* 2022;**9**:781.
18. Clappison E, Hadjivassiliou M, Zis P. Psychiatric manifestations of coeliac disease, a systematic review and meta-analysis. *Nutrients* 2020;**12**:142.
19. Zambrano S, Parma B, Morabito V, et al. Celiac disease in autism spectrum disorder: data from an Italian child cohort. *Ital J Pediatr* 2023;**49**:79.
20. Kedem S, Yust-Katz S, Carter D, et al. Attention deficit hyperactivity disorder and gastrointestinal morbidity in a large cohort of young adults. *World J Gastroenterol* 2020;**26**:6626-6637.
21. Madra M, Ringel R, Margolis KG. Gastrointestinal issues and autism spectrum disorder. *Child Adolesc Psychiatr Clin N Am* 2020;**29**:501-513.
22. Kumar A, Vallabhaneni P. Anxiety disorders presenting as gastrointestinal symptoms in children - a scoping review. *Clin Exp Pediatr* 2025;**68**:344-351.
23. Farris SG, Derby L, Kibbey MM. Getting comfortable with physical discomfort: a scoping review of interoceptive exposure in physical and mental health conditions. *Psychol Bull* 2025;**151**:131-191.
24. Gianneschi JR, Washington KA, Nicholas J, et al. Assessing fears of negative consequences in children with symptoms of avoidant restrictive food intake disorder. *Int J Eat Disord* 2024;**57**: 2329-2340.
25. Wu MS, Rudy BM, Arnold EB, Storch EA. Phenomenology, clinical correlates, and impairment in emetophobia. *J Cogn Psychother* 2015;**29**:356-368.
26. Carroll MW, Kuenzig ME, Mack DR, et al. The impact of inflammatory bowel disease in Canada 2018: children and adolescents with IBD. *J Can Assoc Gastroenterol* 2019;**2**:S49-S67.
27. Keethy D, Mrakotsky C, Szigethy E. Pediatric inflammatory bowel disease and depression: treatment implications. *Curr Opin Pediatr* 2014;**26**:561-567.
28. Salcudean A, Nan AG, Bodo CR, Cosma MC, Strete EG, Lica MM. Association between childhood onset inflammatory bowel disease and psychiatric comorbidities in adulthood. *Diagnostics (Basel)* 2023;**13**:1868.
29. Mackner LM, Bickmeier RM, Crandall WV. Academic achievement, attendance, and school-related quality of life in pediatric inflammatory bowel disease. *J Dev Behav Pediatr* 2012;**33**:106-111.
30. Mackner LM, Greenley RN, Szigethy E, Herzer M, Deer K, Hommel KA. Psychosocial issues in pediatric inflammatory bowel disease: report of the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition. *J Pediatr Gastroenterol Nutr* 2013;**56**:449-458.
31. Sakaguchi K, Yagi T, Maeda A, et al. Association of problem behavior with sleep problems and gastroesophageal reflux symptoms. *Pediatr Int* 2014;**56**:24-30.
32. Demir AM. Quality of life in children and adolescents with gastroesophageal reflux disease. *Turkish J Pediatr Dis* 2022;**16**: 235-241.
33. Dutt R, Roduta-Roberts M, Brown CA. Sleep and children with cerebral palsy: a review of current evidence and environmental non-pharmacological interventions. *Children (Basel)* 2015;**2**:78-88.
34. Böhmer CJ, Klinkenberg-Knol EC, Niezen-de Boer MC, Meuwissen SG. Gastroesophageal reflux disease in intellectually disabled individuals: how often, how serious, how manageable? *Am J Gastroenterol* 2000;**95**:1868-1872.
35. Acierno SP, Chilcote HC, Edwards TC, Goldin AB. Development of a quality of life instrument for pediatric gastroesophageal reflux disease: qualitative interviews. *J Pediatr Gastroenterol Nutr* 2010;**50**:486-492.
36. Rosen R, Vandenplas Y, Singendonk M, et al. Pediatric gastroesophageal reflux clinical practice guidelines: joint recommendations of the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition and the European Society for Pediatric Gastroenterology, Hepatology, and Nutrition. *J Pediatr Gastroenterol Nutr* 2018;**66**:516-554.
37. Gonzalez Ayerbe JI, Hauser B, Salvatore S, Vandenplas Y. Diagnosis and management of gastroesophageal reflux disease in infants and children: from guidelines to clinical practice. *Pediatr Gastroenterol Hepatol Nutr* 2019;**22**:107-121.
38. Liu J, Zhao SR, Reyes T. Neurological and epigenetic implications of nutritional deficiencies on psychopathology: conceptualization and review of evidence. *Int J Mol Sci* 2015;**16**:18129-18148.
39. Sohn JK, Keet CA, McGowan EC. Association between allergic disease and developmental disorders in the National Health and Nutrition Examination Survey. *J Allergy Clin Immunol Pract* 2019;**7**:2481-2483.
40. Schimansky S, Jasim H, Pope L, et al. Nutritional blindness from avoidant-restrictive food intake disorder - recommendations for the early diagnosis and multidisciplinary management of children at risk from restrictive eating. *Arch Dis Child* 2024;**109**:181-187.
41. Grajek M, Krupa-Kotara K, Białek-Dratwa A, et al. Nutrition and mental health: a review of current knowledge about the impact of diet on mental health. *Front Nutr* 2022;**9**:943998.
42. Stevens LJ, Kuczek T, Burgess JR, Hurt E, Arnold LE. Dietary sensitivities and ADHD symptoms: thirty-five years of research. *Clin Pediatr (Phila)* 2011;**50**:279-293.
43. McCann D, Barrett A, Cooper A, et al. Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial. *Lancet* 2007;**370**:1560-1567.
44. Millichap JG, Yee MM. The diet factor in attention-deficit/ hyperactivity disorder. *Pediatrics* 2012;**129**:330-337.
45. Pelsser LM, Frankena K, Toorman J, et al. Effects of a restricted elimination diet on the behaviour of children with attention-deficit hyperactivity disorder (INCA study): a randomised controlled trial. *Lancet* 2011;**377**:494-503.
46. Banks WA, Gray AM, Erickson MA, et al. Lipopolysaccharide-induced blood-brain barrier disruption: roles of cyclooxygenase, oxidative stress, neuroinflammation, and elements of the neurovascular unit. *J Neuroinflammation* 2015;**12**:223.
47. Cryan JF, Dinan TG. Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nat Rev Neurosci* 2012;**13**:701-712.
48. Ratsika A, Codagnone MC, O'Mahony S, Stanton C, Cryan JF. Priming for life: early life nutrition and the microbiota-gut-brain axis. *Nutrients* 2021;**13**:423.
49. Rupp S, Papaefthymiou A, Chatzimichael E, et al. Diagnostic approach to *Helicobacter pylori*-related gastric oncogenesis. *Ann Gastroenterol* 2022;**35**:333-344.
50. Doulberis M, Srivastava S, Polyzos SA, et al. Active *Helicobacter pylori* infection is independently associated with nonalcoholic steatohepatitis in morbidly obese patients. *J Clin Med* 2020;**9**:933.
51. Doulberis M, Kotronis G, Thomann R, et al. Review: Impact of *Helicobacter pylori* on Alzheimer's disease: what do we know so far? *Helicobacter* 2018;**23**:e12454.
52. Doulberis M, Papaefthymiou A, Polyzos SA, et al. Impact of *Helicobacter pylori* and metabolic syndrome-related mast cell activation on cardiovascular diseases. *Front Gastroenterol* 2024;**3**:1331330.
53. Kountouras J, Boziki M, Gavalas E, et al. Increased cerebrospinal fluid *Helicobacter pylori* antibody in Alzheimer's disease. *Int J Neurosci* 2009;**119**:765-777.
54. Gemilyan M, Hakobyan G, Benejat L, et al. Prevalence of *Helicobacter pylori* infection and antibiotic resistance profile in

Armenia. *Gut Pathog* 2019;**11**:28.
55. Abass MGA, I. Zaher TI, Elnimr SA, Atta AHM, Morad EA. Relationship between hepcidin and iron deficiency anemia in *Helicobacter pylori* infected patients. *Egypt J Med Microbiol* 2021;**30**:21-27.
56. Kaipainen P, Kaski M. *Helicobacter pylori* infection and atrophic corpus gastritis on patients with intellectual disability: challenges in the clinical translation of personalized medicine. In: Atroshi F (editor) Personalized medicine, in relation to redox state, diet and lifestyle. London, UK, IntechOpen, 2020, pp 1-17.
57. Romo-González C, Mendoza E, Mera RM, et al. *Helicobacter pylori* infection and serum leptin, obestatin, and ghrelin levels in Mexican schoolchildren. *Pediatr Res* 2017;**82**:607-613.