

Neurodevelopmental Function and Dysfunction in the School-Age Child

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Nelson Textbook of Pediatrics ([#!/browse/book/3-s2.0-C20120035867](#)), Chapter 32, 192-199.e1

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Terminology and Epidemiology

A **neurodevelopmental function** is a basic brain process needed for learning and productivity.

Neurodevelopmental variation refers to differences in neurodevelopmental functioning. Wide variations in these functions exist within and between individuals. These differences can change over time and need not represent pathology or abnormality.

Neurodevelopmental dysfunctions reflect disruptions of neuroanatomic structure or psychophysiologic function and place a child at-risk for developmental, cognitive, emotional, behavioral, psychosocial and adaptive challenges. For the school-age child, an area of particular focus is academic skill development. Academic disorders have been diagnostically classified as **Specific Learning Disorder** (SLD) by the revised *Diagnostic and Statistical Manual of Mental Disorder Fifth Edition* (DSM-5). Changes in DSM-5 (compared to DSM-IV) involve a broadening of the diagnostic criteria in an effort to recognize factors that may interrupt the effective acquisition of academic skills that include **reading**, **written language**, **spelling** and **mathematics**. The *International Classification of Diseases* (ICD) of the World Health Organization, 10th Edition (ICD-10) categorizes **Specific Developmental Disorders of Scholastic Skills** that include **Reading Disorder**, **Spelling Disorder**, **Disorder of Arithmetical Skills**, and **Mixed Disorder of Scholastic Skills**. **Dyslexia** (reading disorder) is included in ICD-10 in a separate category of symbolic dysfunction. The terms, **Dyscalculia** (mathematics disorder), and **Dysgraphia** (written language disorder) are also used by investigators and clinicians, but their inclusion in diagnostic classification systems has been inconsistent and a source of some disagreement among experts.

Traditionally, the educational system has identified SLDs through the process of psychoeducational testing. Through this process, students experiencing academic problems would be evaluated psychometrically. Typical testing batteries have usually included measures of overall intelligence and academic skills. A student exhibiting a significant discrepancy between scores on tests of intelligence and tests of academic achievement could be classified as a student with an SLD, and would subsequently be eligible for Special Education Services. The degree of discrepancy required for such classification often differed between states and even between school districts. In a marked change in approach to the identification of SLDs, the reauthorization of the Individuals with Disabilities Education Act (IDEA) in 2004 introduced the Response to Intervention (RTI) model, which does not necessitate that schools use the discrepancy model for determining if a student has an SLD. Instead, schools may employ research-based intervention approaches and monitor a student's response to that intervention before initiating psychoeducational testing. This approach has been met with some disapproval, as those who challenge its effectiveness argue that the RTI model, in and of itself, should not be used to identify children with SLD. The

underlying view behind this objection rests with the notion that children may fail to respond to RTI for a variety of reasons (e.g., underlying neurocognitive weakness), not just because a SLD exists.

Overall estimates of the prevalence of SLD's range from 3-10%. Some data indicate that approximately 8% of children 3-17 yr of age have, at one point, been identified as having a SLD. Prevalence estimates can vary owing to numerous factors, including differences in definitions and criteria used for classification and diagnosis, as well as differences in methods of assessment.

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Etiology and Pathogenesis

Neurodevelopmental dysfunction may present for any number of reasons. These include pre-/perinatal, genetic, medical, psychologic, environmental and sociocultural influences. Genes that contribute to neurodevelopmental dysfunction have been identified. Reading disorders can be both familial and heritable, and studies have linked some reading disabilities to specific gene loci on chromosomes 6 and 15. Chromosomal abnormalities can lead to unique patterns of dysfunction, such as visual-spatial deficits in girls diagnosed with Turner syndrome or language deficits in children with fragile X syndrome (see [Chapter 81 \(#/content/3-s2.0-B9781455775668000818?scrollTo=%23c00081\)](#)). Chromosome 22q11.2 deletion syndrome (DiGeorge or velocardiofacial syndrome [see [Chapter 125 \(#/content/3-s2.0-B9781455775668001253?scrollTo=%23c00125\)](#)]) is associated with predictable patterns of neurodevelopmental dysfunction, including a higher prevalence of intellectual disability, and deficits in visual-spatial processing, executive function, attention, working memory, verbal learning, arithmetic, and language with relative strengths in selected reading and spelling skills. Investigations of the neuroanatomical substrates have also yielded important information about the underlying causes of neurodevelopmental dysfunction. Multiple investigations have identified differences in the left parietotemporal and left occipitotemporal brain regions of individuals with dyslexia compared to those without reading difficulties (see [Chapter 34 \(#/content/3-s2.0-B978145577566800034X?scrollTo=%23c00034\)](#)). Studies also describe the neural circuitry, primarily in the parietal cortex, underlying mathematical competencies such as the processing of numerical magnitude, and mental arithmetic investigations support a broader role for the white matter in active learning and memory than was previously estimated.

Perinatal risk factors that are associated with neurodevelopmental dysfunction include very-low birthweight, severe intrauterine growth restriction, perinatal hypoxic-ischemia encephalopathy, and prenatal exposure to substances such as alcohol and drugs (see [Chapter 96 \(#/content/3-s2.0-B978145577566800096X?scrollTo=%23c00096\)](#)). Increased risk of academic and frontal lobe disorders also is associated with environmental toxins, including lead (see [Chapter 721 \(#/content/3-s2.0-B9781455775668007213?scrollTo=%23c00721\)](#)); drugs such as cocaine; infections such as meningitis and HIV; and brain injury secondary to intraventricular hemorrhage, periventricular leukomalacia, or head trauma.

Early psychologic trauma can result in both structural and neurochemical changes in the developing brain, which may contribute to neurodevelopmental dysfunction. Findings suggest that the effects of exposure to trauma (see [Chapter 39 \(#/content/3-s2.0-B9781455775668000399?scrollTo=%23c00039\)](#)) and/or abuse (see [Chapter 40 \(#/content/3-s2.0-B9781455775668000405?scrollTo=%23c00040\)](#)) early in the developmental course can induce disruption of the brain's regulatory system with connections in the orbitofrontal cortex, and may influence right-hemisphere function with associated risk for problems with information processing, memory, and frontal lobe related operations (e.g., focus and self-regulation). Environmental and sociocultural deprivation can lead to, or potentiate, neurodevelopmental dysfunction, which most often results from a combination of contributing factors, rather than a single cause.



Core Neurodevelopmental Functions

The neurodevelopmental processes that are critical for academic success may best be understood as falling within **core neurodevelopmental domains**.



Sensory and Motor Development

Sensory development (e.g., auditory, visual, tactile, proprioceptive) begins well before birth. This neurodevelopmental process is crucial in helping children experience, understand, and manipulate their environments. Through sensory experiences, children's brains mature as new neuronal pathways are created and existing pathways are strengthened. Any interruption of this process may result in sensory-motor deficits and delays (e.g., apraxia) that can interfere with early development and academic performance.

Sensory development for the school-age child progresses in association with environmental exposure and with the development of other cognitive processes such as motor development.

There are 3 distinct, yet related, forms of neuromotor ability: graphomotor, fine motor, and gross motor coordination.

Graphomotor function refers to the specific motor aspects of written output. Several subtypes of graphomotor dysfunction significantly impede writing. Some children harbor weaknesses of visualization during writing. They have trouble picturing the configurations of letters and words as they write (orthographics). Their written output tends to be poorly legible, with inconsistent spacing between words. Others have weaknesses in orthographic memory, which interferes with their ability to recall and/or reproduce letter and number forms rapidly and accurately. They may labor over individual letters and prefer printing (manuscript) to cursive writing. Some exhibit signs of finger agnosia or weak graphomotor feedback; they have trouble localizing their fingers while they write. As a result, they need to keep their eyes very close to the page and tend to apply excessive pressure to the pencil. Others struggle with graphomotor production deficits. For these children, trouble producing the highly coordinated motor sequences needed for writing results in difficulty assigning writing roles to specific muscle groups in their hands. This phenomenon has also been described as **dyspraxic dysgraphia**. It is important to emphasize that a child may show excellent fine motor dexterity (as revealed in mechanical or artistic domains) but very poor graphomotor fluency (with labored or poorly legible writing).

For the school-age child, problems with **fine motor function** can disrupt their ability to communicate in written form, to excel in artistic and crafts activities, and can interfere with learning a musical instrument or mastering a computer keyboard. The term **dyspraxia** relates to difficulty in developing an ideomotor plan and activating coordinated and integrated visual motor actions to complete a task or solve a motor problem, such as assembling a model.

Some children exhibit **gross motor incoordination**. They have problems in processing "outer spatial" information to guide gross motor actions. Affected children may be inept at catching or throwing a ball because they cannot form accurate judgments about trajectories in space. Others demonstrate diminished body position sense. They do not efficiently receive or interpret proprioceptive and kinesthetic feedback from peripheral joints and muscles. They are likely to evidence difficulties when activities demand balance and ongoing tracking of body movement. Others are unable to satisfy the motor praxis demands of certain gross motor activities. It may be hard for them to recall or plan complex motor procedures such as those needed for dancing, gymnastics, or swimming.

Children with gross motor problems can incur considerable embarrassment in physical education classes. Gross motor weaknesses can lead to social rejection, withdrawal, and generalized feelings of inadequacy.

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Language

Language is one of the most critical and complex cognitive functions and can be broadly divided into **receptive** (auditory comprehension/understanding) and **expressive** (speech and language production and/or communication) functions. Children who primarily experience receptive language problems may have difficulty understanding verbal information, following instructions and explanations, and interpreting what they hear. Expressive language weaknesses can result from problems with speech production and/or problems with higher level language development (see [Chapter 35 \(#/content/3-s2.0-B9781455775668000351?scrollTo=%23c00035\)](#)). Speech production difficulties include oromotor problems affecting articulation, verbal fluency, and naming. Some children have trouble with sound sequencing within words. Others find it hard to regulate the rhythm or prosody of their verbal output. Their speech may be dysfluent, hesitant, and inappropriate in tone. Problems with word retrieval can result in problems in finding exact words when needed (as in a class discussion) or substituting definitions for words (circumlocution). Children who evidence higher level expressive language impediments have trouble formulating sentences, using grammar acceptably, and organizing spoken (and possibly written) narratives.

In considering disordered language, whether in reception or expression, it is vital to ascertain the potential underlying difficulties that are contributing. Some children, for example, have particular problems with **phonology** (see [Chapter 35 \(#/content/3-s2.0-B9781455775668000351?scrollTo=%23c00035\)](#)). Commonly, a weak phonologic sense has a negative effect not only on language processing, but also on the development of reading, writing and even mathematics (e.g., word problems). Children with **semantic deficits** have trouble learning the meaning of words, and as a result, may use words improperly (e.g., out of context). Other common language deficiencies include difficulty with **syntax** (word order), problems with **discourse** (paragraphs and passages), an underdeveloped sense of **metalinguistics** (the ability to think about and analyze how language works), and trouble with drawing appropriate inferences (supplying missing information) from language. Difficulty with language **pragmatics**, or the social understanding and application of language, can be another significant impediment.

Language weaknesses not only contribute to problems with reading, writing and math, but can also manifest in the content areas, such as the sciences, which necessitate the processing of dense verbal material in textbooks and the rapid convergent recall of facts, and social studies courses that often entail the use of sophisticated language and verbal abstract concepts (e.g., democracy). Learning foreign languages can be a serious problem. In contrast, children who possess strong language skills are often able to make use of their linguistic facility to compensate for any academic problems; it may be possible to verbalize one's way through a mathematics curriculum, thereby circumventing a tendency to be confused by predominantly nonverbal concepts (e.g., ratio, equation, and diameter).

To one degree or another, all academic skills are taught largely through language, and thus it is not surprising that children who experience language dysfunction often experience problems with academic performance. In fact, some studies suggest that up to 80% of children who present with a SLD also experience language-based weaknesses.

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Visual–Spatial/Visual–Perceptual Function

The process of visual development begins well before birth, with continued development and refinement throughout childhood (see [Chapter 621 \(#/content/3-s2.0-B97814557756680006219?scrollTo=%23c00621\)](#)). Important structures involved in the development and function of the visual system, beyond the eyes themselves, include the retina, optic

cells (e.g., rods and cones), the optic chiasm, the optic nerves, the brainstem (control of automatic responses like pupil dilation), the thalamus (e.g., lateral geniculate nucleus for form, motion, color), and the primary (visual space and orientation) and secondary (color perception) visual processing regions located in and around the occipital lobe. Other brain areas, considered to be outside of the primary visual system, are also important to visual function, helping to process *what* (temporal lobe) is seen and *where* it is located in space (parietal lobe). The left and right cerebral hemispheres interact considerably in visual processes, with each hemisphere possessing more specialized functions, including left hemisphere mediated processing of details, patterns, and linear information, and right hemisphere processing of the gestalt and overall form.

Some of the more critical aspects of visual processing to develop in the school-age child include **spatial relations** — the ability to accurately perceive objects in space in relation to other objects; **visual discrimination**— the ability to differentiate and identify objects based on their individual attributes such as size, shape, color, form, and position; and, **visual closure**— the ability to recognize or identify an object even when the entire object cannot be seen.

Children with subtle visual deficits are often misidentified and/or missed completely. Indications of visual processing deficits in the school-age child may include difficulty learning to draw and write, and problems with art activities. These children might also have trouble discriminating between left and right. They might encounter problems recognizing letters and words, resulting in delayed reading, spelling, and writing.

Visual–spatial processing dysfunctions are not a common cause of chronic reading disorders, but more recent investigations have established that deficits in orthographic coding (visual–spatial analysis of character-based systems) can contribute to reading disorders. Spelling and writing can emerge as a weakness because children with visual processing problems commonly have trouble with the precise visual configurations of words. In mathematics, these children often have difficulty with visual–spatial orientation, with resultant difficulty aligning digits in columns when performing calculations and/or difficulty managing geometric material. In the social realm, intact visual processing allows a child to make use of visual or physical cues when communicating and interpreting the paralinguistic aspects of language. Secure visual functions are also necessary to process proprioceptive and kinesthetic feedback and to coordinate movements during physical activities. Children with visual processing deficits are thus susceptible to problems such as social isolation and withdrawal and consequent behavioral and/or emotional difficulties.

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Intellectual Function

The concept of intellectual function, or intelligence, has had many definitions and theoretical models, and achieving a consensus on the subject has been challenging. Well-known theories include Spearman's unitary concept of “the g-factor,” the “verbal and nonverbal” theories (e.g., Binet, Thorndike), the 2-factor theory from Cattell (crystallized vs fluid intelligence), Luria's simultaneous and successive processing model, and more recent models that view intelligence as a global construct composed of more-specific cognitive functions (e.g., auditory and visual–perceptual processing, spatial abilities, processing speed, and working memory). A useful definition of **intellectual function** is the capacity to think in the abstract, reason, problem solve and comprehend.

The expression of intellect is mediated by many factors, including language development, sensorimotor abilities, genetics, heredity, environment, and neurodevelopmental dysfunction or neuropathology. When an individual's intelligence is measured at a standard score of 70 or lower, and significant weaknesses in adaptive skills are indicated, consideration of the diagnosis of Intellectual Disability would be warranted. In DSM-5, the previous

diagnostic term of Mental Retardation has been changed to **Intellectual Disability**. DSM-5 also includes the term **Intellectual Developmental Disorder** to indicate weaknesses in intellectual functioning that begin during the early developmental period ([Chapter 36 \(#/content/3-s2.0-B9781455775668000363?scrollTo=%23c00036\)](#)).

The clinical assessment of intellectual functioning has proved useful in identifying intellectual disability, informing treatment strategies, and in predicting future functionality (e.g., academic, occupational and social).

Notwithstanding, intelligence test scores (e.g., IQ) reflect only part of an individual's ability profile. Functionally, there are some common characteristics that distinguish children with deficient intellectual functioning from those with average or above average abilities. Typically, those at the lowest end of the spectrum (e.g., profound or severe intellectual deficiencies) are incapable of independent function, and require a highly structured environment with constant aid and supervision (see [Chapter 36 \(#/content/3-s2.0-B9781455775668000363?scrollTo=%23c00036\)](#)). At the other end of the spectrum are those with unusually well-developed intellect (e.g., gifted). Although this level of intellectual functioning offers many opportunities, it can also be associated with functional challenges related to socialization, learning style, and communication and perceptual differences. Individuals whose intellect falls in the below average range (sometimes referred to as the “borderline” or “*slow learner*” range) tend to experience greater difficulty processing and managing information that is abstract, making connections between concepts and ideas, and generalizing information (e.g., may be able to comprehend a concept in one setting but are unable to carry it over and apply it in different situation). In general, these individuals tend to do better when information is presented in more concrete and explicit terms, and when working with rote information (e.g., memorizing specific material). Stronger intellect is associated with better-developed concept formation, critical thinking, problem solving, understanding and formulation of rules, brainstorming and creativity, and metacognition (the ability to “think about thinking”)

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Frontal Lobe Functioning

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Attention

Most brain processes are heavily dependent on functional arousal, alertness, and attention. Any malfunction within or across these systems will likely cause some degree of breakdown in other cognitive processes. Functional attention subsumes intact neuroanatomic and neurochemical brain systems. Structurally, brain regions involved include subcortical, cortical, and association areas throughout the brain. Primary structures involved include brainstem regions (e.g., basal ganglia), the limbic system (e.g., amygdala and hippocampus), and the frontal lobes (e.g., prefrontal cortex). The neurotransmitter dopamine, along with its neuronal pathways, has been identified as a major chemical modulator of attention. It is through the cognitive mechanisms of attention and executive functions that the child's brain acquires, organizes, and processes information. These mechanisms also allow the child to regulate, plan, and monitor their behaviors and thoughts. Children with attention dysfunction comprise a widely heterogeneous group who show various patterns of impairment of these systems (see [Chapter 33 \(#/content/3-s2.0-B9781455775668000338?scrollTo=%23c00033\)](#)). The resulting symptoms not only affect behavior, learning, and academic skills development, but also have an impact on the child's emotional, social, and adaptive development and functioning.

Attention is far from a unitary, independent, or specific function. This may be illustrated best through the phenotype associated with **Attention-Deficit/Hyperactivity Disorder (ADHD)**. ADHD is not only a disorder of impaired focus, but also includes a host of symptoms related to problems with vigilance, distractibility, impulsivity in thought and behavior, hyperactivity, and flexibility. Disordered attention can occur owing to faulty

mechanisms in and/or across subdomains of attention. These subdomains include **selective attention** (the ability to focus attention to a particular stimulus and to discriminate relevant from irrelevant information), **divided attention** (the ability to orient to more than one stimulus at a given time), **sustained attention** (the ability to maintain one's focus), and **alternating attention** (the capacity to shift focus between stimuli).

Attention problems in school-age children can manifest at any point in the process, from arousal through output. Children with diminished alertness and arousal can exhibit signs of mental fatigue in a classroom or when engaged in any activity requiring sustained focus. They might yawn, stretch, fidget, and daydream. They can become overactive in an effort to attain or maintain a higher level of arousal. They are apt to have difficulty allocating and sustaining their concentration, and their efforts may be erratic and unpredictable, with extreme performance inconsistency. These children can also have difficulty discriminating between important and unimportant information. Such weaknesses of determining saliency often result in focusing on the wrong stimuli, at home, in school, and socially, and can result in the child's missing important information and can impede their ability to take notes, to summarize information, or to recognize what to study for a test. In the social context, poor attention may result in inept social interaction (e.g., because of factors such as not “hearing” what others say). Some children present with what has been termed *sluggish cognitive tempo*. Children with sluggish cognitive tempo have many inattentive features without a history of significant hyperactivity and/or impulsiveness. Some researchers believe that sluggish cognitive tempo may be a different disorder from ADHD, with its own characteristics, including hypoactivity, lethargy, confusion, and mental “fogginess.”

Distractibility can take the form of listening to extraneous noises instead of a teacher, staring out the window, or constantly thinking about the future. These children often show evidence of superficial concentration, where their level of focus is not of sufficient intensity to capture specific information. As a result, these children are often described as “forgetful” because directions and explanations need to be repeated and details (e.g., changes in operational signs in mathematics) may be missed. These children can also exhibit difficulties with cognitive activation and generalization, passively processing and not linking information with prior knowledge and experience, or over-relying on prior experience.

Attention dysfunction can affect the output of work, behavior, and/or social activity. These children have a tendency to perform or act without previewing a likely outcome or thinking through the potential consequences of what they are about to do or say. Their impulsivity can lead to careless mistakes in academic work and unintended misbehavior. It is important to appreciate that most children with attentional dysfunction also harbor other forms of neurodevelopmental dysfunction that can be associated with academic disorders (with some estimates suggesting up to 60% comorbidity).

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Executive Functioning

There is considerable overlap between attention and **executive functioning**. Additions to the ICD classification system include a code for *Frontal Lobe and Executive Function Deficit* (799.55). Executive functioning is an umbrella term used to describe specific cognitive processes involved in regulating, guiding, organizing, and monitoring of thoughts and actions (cognitive, behavioral, and emotional functions) to achieve a specific goal. Processes considered to be executive in nature include inhibition control, flexibility (the ability to shift between activities or thoughts), emotional control, initiation skills, planning, organization, working memory, and self-monitoring.

Studies indicate that executive functioning can be strengthened in children as young as age 4 yr, which suggests that

executive functioning is actively developing in the preschool-age child.

Executive function deficits that have particular impact on school function include **inhibition**, or **inhibitory control**, the ability to control a response, whether it be cognitive or behavioral. Children with inhibitory control deficits may answer questions prematurely and fail to check their work. Behaviorally, these children may speak without first considering the impact of what they say. In the social context, disinhibited children may interrupt others and demonstrate other impulsive behaviors that often interfere with interpersonal relationships (see [Chapter 33 \(#/content/3-s2.0-B9781455775668000338?scrollTo=%23c00033\)](#)).

The function of **working memory** has been the focus of significant research efforts. Working memory can be defined as the ability to hold, manipulate, and store information for short periods. In its simplest form, working memory involves the interaction of short-term verbal and visual processes (e.g., memory, phonologic, awareness and spatial skills) with a centralized control mechanism that is responsible for coordinating all of the cognitive processes involved (e.g., temporarily suspending information in memory while working with it). Developmentally, working memory capacity can double or triple between the preschool years and adolescence. A child with working memory dysfunction might carry a number and then forget what it was that the child intended to do after carrying that number. Working memory is an equally important underlying function for reading, where it enables the child to remember the beginning of a paragraph when the child arrives at the end of it. In writing, working memory helps children remember what they intend to express in written form while they are performing another task, like placing a comma or working on spelling a word correctly. Working memory also enables the linkage between new incoming information in short-term memory with prior knowledge or skills held in longer-term memory ([Table 32-1 \(t0010\)](#)).

Table 32-1

Symptom Expression of Executive Dysfunction

EXECUTIVE FUNCTION DEFICIT	SYMPTOM EXPRESSION
Disinhibition	Impulsivity/poor behavioral regulation Interrupts “Blurts” things out
Shifting	Problems with transitioning from one task/activity to another Unable to adjust to unexpected change Repeats unsuccessful problem-solving approaches
Initiation	Difficulty independently beginning tasks/activities Lacks initiative Difficulty developing ideas or making decisions
Working memory	Challenges following multistep instruction (e.g., only completes 1 of 3 steps) Forgetfulness

Organization and planning	<p>Fails to plan ahead</p> <p>Work is often disorganized</p> <p>Procrastinates and does not complete tasks</p> <p>“Messy” child</p>
Self-monitoring	<p>Fails to recognize errors and check work</p> <p>Does not appreciate impact of actions on others</p> <p>Poor self-awareness</p>
Affect control	<p>Experiences behavioral and emotional outbursts (e.g., tantrums)</p> <p>Easily upset/frustrated</p> <p>Frequent mod changes</p>

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Memory

Memory is a term used to describe the cognitive mechanism by which information is acquired, retained, and recalled. Structurally, some major brain areas involved in memory processing include the hippocampus, the fornix, the temporal lobes, and the cerebellum, with connections in and between most brain regions. The memory system can be partitioned into subsystems based on processing sequences; the form, time span, and method of recall; whether memories are conscious or unconsciously recalled; and the types of memory impairments that can occur.

Once information has been identified (through auditory, visual, tactile, and/or other sensory processes), it needs to be **encoded and registered**, a mental process that constructs a representation of the information into the memory system. The period of time (typically seconds) during which this information is being held and/or manipulated for registration, and ultimately encoded, consolidated, and retained, is referred to as **working memory** (see above). Other descriptors include **short-term memory** and **immediate memory**.

Consolidation and **storage** represent the process by which information in short-term memory is transferred into **long-term memory**. Information in long-term memory can be available for hours or as long as a life span. Long-term memories are generally thought to be housed, in whole or in part, in specific brain regions (e.g., the cortex, cerebellum). Ordinarily, consolidation in long-term memory is accomplished in 1 or more of 4 ways: pairing 2 bits of information (such as a group of letters and the English sound it represents); storing procedures (consolidating new skills, such as the steps in solving mathematics problems); classifying data in categories (filing all insects together in memory); and linking new information to established rules, patterns, or systems of organization (rule-based learning).

Once information finds its way into long-term memory, it must be accessed. In general, information can be retrieved spontaneously (a process known as **free recall**) or with the aid of cues (**cued or recognition recall**). Some other common descriptors of memory include **anterograde memory** (the capacity to learn from a single point in time forward), **retrograde memory** (the capacity to recall information that was already learned), and **explicit memory** (conscious awareness of recall), **implicit memory** (subconscious recall: no awareness that the memory system is being activated), **procedural memory** (memory for how to do things), and **prospective**

memory or *remembering to remember* .

As children proceed through school, the demands for the efficient use of memory progressively increase. By secondary school, rapid and precise recall is heavily emphasized. Children can have trouble with 1 or more memory mechanisms. They might struggle with the initial registration of information in short-term memory. Others might have difficulty storing newly introduced information. Other children might have difficulty accessing (retrieving) information, despite having registered and stored it effectively. Children can experience frustration in their efforts at consolidating information into long-term memory and/or encounter difficulty with simultaneous recall (retrieval of several facts or procedures at once). Some students exhibit delayed **automatization**: not enough of what they have learned in the past is accessible to them instantaneously and with no expenditure of effort. Such skills as forming letters, mastering mathematical facts, and decoding words must ultimately become automatic if students are to make good academic progress.

Weaknesses with memory processing can be highly specific and/or dependent on the material. Some children struggle to learn visual-spatial material, whereas others may be deficient in learning auditory information. Some have difficulty processing linear data or sequential information. Some can experience difficulty with rote data (e.g., word lists) yet have little or no difficulty registering information in context (e.g., a narrative). Although in-depth examination (e.g., neuropsychologic testing) is often necessary to differentiate potential memory weaknesses and their impact on the child's overall functioning, screening for memory problems should be part of any well-child examination.

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Social Cognition

For the school-age child, the development and effective use of social skills is of immeasurable importance. It is heavily dependent on secure **social cognition** , which is composed of mental processes that allow an individual to understand and interact with the social environment. Although some evidence shows that social cognition exists as a discrete area of neurodevelopmental function, multiple cognitive processes are involved with social cognition. These include the ability to recognize, interpret, and make sense of the thoughts, communications (verbal and nonverbal), and actions of others, the ability to understand that others' perceptions, perspectives, and intentions might differ from our own (commonly referred to as “theory of mind”), the ability to use language to communicate with others socially (pragmatic language), and the ability to make inferences about others and/or the environment based on contextual information. It can also be argued that social cognition involves processes associated with memory and executive functions like flexibility.

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Clinical Manifestations

School-age children with neurodevelopmental dysfunctions vary widely with regard to clinical presentations. Their specific patterns of academic performance and behavior represent final common pathways, the convergence of many forces, including interacting cognitive strengths and deficits; environmental, social, or cultural factors; temperament; educational experience; and intrinsic resilience ([Table 32-2 \(t0015\)](#)). Symptoms of academic disorders differ with age. Children in preschool or kindergarten might present with delayed language development, including problems with articulation, vocabulary development, word finding and rhyming. They often experience early challenges with learning colors, shapes, letters and numbers, the alphabet, and days of the week. Difficulty following instructions, overactivity, and distractibility may be early symptoms of emerging attention and inhibitory control weaknesses. Difficulties with fine motor development (e.g., grasping crayons and pencils, coloring or

drawing) and social interaction are not uncommon. As these children enter elementary school, they can evidence problems integrating and associating letters and sounds and problems with semantic knowledge such as mixing up their words (like go and eat). While learning to read and spell, challenges with reversals (b/d), inversions (m/w), transpositions (felt/left), and substitutions (house/home) might persist. Reading comprehension may be weak. (1)

Table 32-2

Neurodevelopmental Dysfunction Underlying Academic Disorders

ACADEMIC DISORDER	POTENTIAL UNDERLYING NEURODEVELOPMENTAL DYSFUNCTION
Reading	Language <ul style="list-style-type: none"> • Phonologic processing • Verbal fluency • Syntactic and semantic skills Memory <ul style="list-style-type: none"> • Working memory Sequencing Visual–spatial Attention
Written expression, spelling	Language <ul style="list-style-type: none"> • Phonologic processing • Syntactic and semantic skills Graphomotor Visual–spatial Memory <ul style="list-style-type: none"> • Working memory Sequencing Attention
Mathematics	Visual–spatial Memory <ul style="list-style-type: none"> • Working memory Language Sequencing Graphomotor

Isolated neurodevelopmental dysfunction can lead to a specific academic disorder, but more often there is a combination of factors underlying weak academic performance. In addition to the dysfunction in neurodevelopmental domains as listed in the table, the clinician must also consider the possibility of limitations of intellectual and cognitive abilities or associated social and emotional problems.

Children with early signs of a mathematics weakness might have difficulty with concepts of quantity or with adding or subtracting without using concrete representation (e.g., their fingers when calculating). Difficulty learning time concepts and confusion with directions (right/left) might also be observed. Sequencing problems are noted in reading, spelling and writing, and mathematics. Poor fine motor control and coordination and poor planning can lead to spelling and writing problems. Attention and behavioral regulation weaknesses observed earlier can continue, and together with executive functioning weaknesses (e.g., organization, initiation skills), further complicate the child's ability to acquire and generalize new knowledge.

Middle school brings with it a significant shift in cognitive, academic, and regulatory demands, as children in this age group are expected to be increasingly independent, causing further difficulties for a child with existing attention, inhibitory, and/or executive challenges. In reading and writing, middle school children might present with transposition and sequencing errors; might struggle with root words, prefixes, and suffixes; might have difficulty with written expression; and might avoid reading and writing altogether. Challenges completing word problems in math are common. Difficulty with recall of information might also be experienced. Although observable in both lower and more advanced grades, behavioral, emotional, and/or social difficulties tend to become more salient in middle school children who experience cognitive and/or academic problems.

Many of these challenges continue well into high school. High school students can present with deficient reading comprehension, written expression, and slower processing efficiency. Trouble answering open-ended questions, dealing with abstract information, and producing executive control (e.g., self-monitoring, organization, planning, and self-starting) is often reported.

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Reading

Reading disorders (see [Chapter 34 \(#//content/3-s2.0-B978145577566800034X?scrollTo=%23c00034\)](#)), also termed **dyslexia**, can stem from any number of neurodevelopmental dysfunctions as described earlier (see [Table 32-2 \(t0015\)](#)). Most commonly, language and/or auditory processing weaknesses are present as evidenced by poor **phonologic processing**. Challenges with phonologic processing often result in deficiencies at the level of decoding individual words and, consequently, a delay in automaticity (e.g., acquiring a repertoire of words they can identify instantly) that causes reading to be slow, laborious, and frustrating. Without effective identification and intervention, reading comprehension, and ultimately the acquisition of knowledge may be seriously compromised. Deficits in other core neurodevelopmental domains might also be present. Weak working memory might make it difficult for a child to hold sounds and/or symbols in mind while breaking down words into their component sounds or might cause reading comprehension problems. Some children experience temporal-ordering weaknesses and struggle with reblending phonemes into correct sequences. Memory dysfunction can cause problems with recall and summarization of what was read. Some children with higher-order cognitive deficiencies have trouble understanding what they read because they lack a strong grasp of the concepts in a text. Although relatively rare as a cause of reading difficulty, problems with visual-spatial functions (e.g., visual perception) can cause children

difficulty in recognizing letters. It is not unusual for children with reading problems to avoid reading practice, and a delay in reading proficiency becomes increasingly pronounced and difficult to remediate.

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Spelling and Writing

Spelling and writing impairments share many related underlying processing deficits with reading, so it is not surprising that the 2 disorders often occur simultaneously in school-age children (see [Table 32-2 \(t0015\)](#)). Core neurodevelopmental weaknesses can include phonologic and decoding difficulties, **orthographic** problems (coding letters and words into memory), and **morphologic** deficits (use of suffixes, prefixes, and root words). Problems in these areas can manifest as phonetically poor, yet visually comparable approximations to the actual word (*faght* for *fight*), spelling that is phonetically correct but visually incorrect (*fite* for *fight*), and inadequate spelling patterns (*played* as *plade*). Children with memory disorders might misspell words because of coding weaknesses. Others misspell because of poor auditory working memory that interferes with their ability to process letters. Sequencing weaknesses often result in transposition errors when spelling. Overall, the careful analysis of a child's errors can provide valuable insights into the nature of their spelling problems. As children proceed through school, demands increase for large amounts of well-organized written output.

Writing difficulties have been classified as **disorder of written expression**, or **dysgraphia** (see [Table 32-2 \(t0015\)](#)). Although many of the same dysfunctions described for reading and spelling can contribute to problems with writing, written expression is the most complex of the language arts, requiring synthesis of many neurodevelopmental functions (e.g., auditory, visual–spatial, memory, executive). Deficits in any of these domains can be problematic. Even when a child's phonologic and/or orthographic skills are functional, the child can experience writing problems owing to weaknesses with language, attention, sequencing and/or fine motor development. These weaknesses can occur in written output that is difficult to comprehend, disjointed, and/or poorly organized. The child with working memory challenges can lose track of what the child intended to write. Attention deficits can make it hard for a child to mobilize and sustain the mental effort, pacing, and self-monitoring demands necessary for writing. In many cases, writing is laborious because of an underlying graphomotor dysfunction (e.g., fluency does not keep pace with ideation and language production). Thoughts may also be forgotten or underdeveloped during writing because the mechanical effort is so taxing.

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Mathematics

Delays in mathematical ability, known as **mathematics disorder** or **dyscalculia**, can be especially refractory to correction, partly because math involves the assimilation of both procedural knowledge (e.g., calculations) and higher-order cognitive processes (e.g., working memory) (see [Table 32-2 \(t0015\)](#)). A school-based study found that no student who was delayed for longer than 6 mo in mathematics in 6th grade ever caught up; another study found persistence of severe arithmetic disorder in half of affected preteen children. Factors associated with persistence of difficulties included the disorder's severity and heritability. Significant mathematical weaknesses can become virtually insurmountable because the subject is so cumulative in its structure.

Some children experience mathematics failure because of weaknesses in reasoning and problem solving (e.g., intellectual functioning). It may be hard for them to grasp and apply concepts effectively and/or systematically. Good mathematicians are able to use both verbal and perceptual conceptualization to understand such concepts as fractions, percentages, equations, and proportion. Children with language dysfunctions have difficulty in mathematics because they have trouble understanding their teachers' verbal explanations of quantitative concepts

and operations and are likely to experience frustration in solving word problems and in processing the vast network of technical vocabulary in math. Mathematics also relies on visualization. Children who have difficulty forming and recalling visual imagery may be at a disadvantage in acquiring mathematical skills. They might experience problems writing numbers correctly, placing value locations, and processing geometric shapes or fractions. Children with attention, inhibitory control, or executive deficits (e.g., working memory) may be unable to focus on fine detail (such as operational signs), might take an impulsive approach to problem solving, engage in little or no self-monitoring, forget components of the same problem, or commit careless errors. When a child's memory system is weak, the child might have difficulty recalling appropriate procedures and automatizing mathematical facts (e.g., multiplication tables). Moreover, it is not unusual for children with mathematical disabilities to have superimposed mathematics phobias. Anxiety over mathematics can be especially debilitating.

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Nonacademic Problems

Neurodevelopmental dysfunctions commonly have effects that extend far beyond academic performance. These effects may be related to the dysfunctions themselves or to secondary sequelae (e.g., persistent failure and frustration). The impulsivity and lack of effective self-monitoring of children with attention and impulse-control deficits can lead to unacceptable actions that were unintentional. Children with neurodevelopmental dysfunctions can experience excessive performance anxiety or clinical depression, and sadness, self-deprecatory comments, declining self-esteem, chronic fatigue, loss of interests, and even suicidal ideation can ensue. Some children lose motivation. They tend to give up and exhibit learned helplessness, a sense that they have no control over their destiny. Therefore, they feel no need to exert effort and develop future goals. These children may be easily led toward dysfunctional interpersonal relationships, detrimental behaviors (e.g., delinquency), and the development of mental health and personality disorders, such as mood disorders (see [Chapter 26 \(#/content/3-s2.0-B9781455775668000260?scrollTo=%23c00026\)](#)) or antisocial personality disorder.

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Assessment and Diagnosis

The primary care pediatrician has a critical role in identifying and evaluating the child with an academic disorder. A system of screening and surveillance should be incorporated into routine office visits to promote early identification of academic difficulties. The pediatrician should be aware of a family medical history that includes a parent who still struggles with reading or time management, or an older sibling who has failed at school. Factors in the child's medical history should be flagged, such as extreme prematurity or chronic medical conditions. Children with low birthweight and those born prematurely who appear to have been spared more serious neurologic problems might only manifest academic problems later in their school career and they warrant particular attention. Children falling into these high risk categories should be flagged for an increased level of scrutiny at routine well-child visits as well as acute-care visits, especially if physical complaints are nonspecific. There should be a low threshold for initiating further school performance screening and assessment of these children. Warning signs might be subtle or absent and problems will not be recognized unless there is a system of eliciting and identifying school problems as part of the routine well-child visit. Parents might have concerns about their child's learning progress but be reluctant to share these with the pediatrician unless prompted such as through completion of a standard developmental screening questionnaires or direct questioning of parents regarding possible concerns about their child's school performance. Inconsistency in report from grade to grade may sometimes be caused by a difference in teaching styles or classroom demands. The type of deficit will also be influential; for example, problems with basic phonemic awareness would be more apparent earlier, while reading comprehension difficulties would emerge later.

Review of school report cards can provide useful clues to patterns of neurodevelopmental dysfunction. In addition to the patterns of grades in the various academic skill areas, it is also important to review ratings of classroom behavior, sometimes listed under headings such as deportment, behavior, conduct, effort/work habits, or citizenship. Review of standardized testing is helpful, and poor scores could be caused by a learning disorder, ADHD, anxiety, lack of motivation, or some combination thereof. Conversely, above-average scores tend to rule out learning or attention problems, but motivation or adjustment issues could then explain a discrepancy between standardized scores and classroom performance. Comparison of how long the homework should take, and how long it takes the child is recommended. Children with ADHD, learning disorders, or emotional/behavioral issues often find homework to be a contentious activity.

The primary care physician is responsible for identifying or ruling out any underlying or associated medical problems that could be impeding the academic performance of the patient who is struggling in school. Vision and hearing screening are critical components of the medical evaluation and any suspicion of sensory difficulty should warrant referral for more definitive testing. The influence of chronic medical problems or potential side effects of medications should be considered. Sleep deprivation is increasingly being recognized as a contributor to academic problems and the possibility of substance abuse must always be a consideration, especially in the adolescent who was previously achieving well at school and has manifested a rapid decline in academic performance.

The physician should be alert for dysmorphic physical features, minor congenital anomalies, or constellations of physical findings (such as cardiac anomalies and palatal anomalies in velocardiofacial syndrome) and should perform a detailed neurologic examination. Special investigations, such as electroencephalograms or brain scans, are not indicated in the absence of specific medical findings. Measures of brain function, such as functional MRI, offer insight into possible areas of neurodevelopmental dysfunction, but they largely remain only research tools with limited application in the general clinical setting at this time.

If problems emerge, the pediatrician should address medical causes or associated conditions. The pediatrician can advise and assist parents in obtaining necessary psychoeducational and/or emotional evaluations through the school or by referral to independent clinicians.

Those physicians with a particular interest in learning disorders can extend their participation in the evaluation process. They can obtain data on neurodevelopmental function through the use of questionnaires completed by the parents, the school, and (if old enough) the child, providing information about behavioral adjustment, patterns of academic performance, and traits associated with specific developmental dysfunctions. Screening instruments such as the Pediatric Symptoms Checklist and standardized behavioral questionnaires, including the Child Behavior Checklist (CBCL) and the Behavior Assessment System for Children—Second Edition (BASC-2) can aid in evaluation (see [Chapter 20 \(#/content/3-s2.0-B978145577566800020X?scrollTo=%23c00020\)](#)).

The physician may also perform an extended neurologic and developmental assessment. Available pediatric neurodevelopmental examination instruments that facilitate direct sampling of various neurodevelopmental functions, such as attention, memory, and language, include the Pediatric Early Elementary Examination (PEEX II) and the Pediatric Examination of Educational Readiness at Middle Childhood (PEERAMID II). Examinations of this type also include direct behavioral observations and assessment of minor neurologic indicators (sometimes called *soft signs*). The latter include various associated movements and other phenomena often associated with neurodevelopmental dysfunction.

A child who is functioning poorly during the school years usually requires a *multidisciplinary evaluation*,

including a pediatrician, a psychologist, and, if possible, a psychoeducational specialist (sometimes called an *educational diagnostician*) who can undertake a detailed analysis of academic skills and subskills. Other professionals should become involved, as needed, in individual cases, such as a speech-language pathologist, an occupational therapist, a neurologist, and a social worker. In some cases, more in-depth examination of a child's neurocognitive status is warranted. This is particularly true for children who present with developmental or cognitive difficulties in the presence of a medical condition (e.g., epilepsy, traumatic brain injury, childhood cancers/brain tumors, genetic conditions). A neuropsychologic evaluation involves comprehensive assessment of brain function as a means of understanding brain function across domains. The goal of neuropsychologic assessment is to understand brain function via identification of a child's profile of cognitive strengths and weaknesses. Neuropsychologic data are often analyzed together with other tests (e.g., structural), such as MRIs, to look for supporting evidence of any areas of difficulty (e.g., memory weaknesses associated with temporal lobe anomalies).

Many children undergo evaluations in school. Such assessments are guaranteed in the United States under Public Law 101-476, the IDEA. In addition, children found to have attentional dysfunction and other disorders might qualify for educational accommodations under Section 504 of the Rehabilitation Act of 1973.

Multidisciplinary evaluations conducted in schools are usually very helpful, but they are focused primarily on determining whether a student meets the eligibility criteria for special education services. School budgeting constraints or lack of personnel can also affect the quality of evaluations and the extent of recommended services. Many parents seek independent evaluations or second opinions outside of the school setting, and pediatricians can facilitate such outside assessments.

Psychoeducational testing can yield relevant data, especially when such assessments include careful analyses that pinpoint where breakdowns are occurring in the processes of reading, spelling, writing, and mathematics. Input from multiple sources can be used in formulating specific recommendations for regular and special educational teachers and for interventions that can be implemented at home. A mental health specialist can be valuable in identifying family-based issues or psychiatric disorders that may be complicating or aggravating neurodevelopmental dysfunctions.

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Treatment

There are a number of standard approaches that should be incorporated into any management plan for a student who is struggling academically. The primary physician can play an important role as a consultant in overseeing and monitoring the implementation of these steps. Management of children with neurodevelopmental dysfunctions often needs to be multidisciplinary. Most children require several of the following forms of intervention.

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Demystification

Many children with neurodevelopmental dysfunctions have little or no understanding of the nature or sources of their academic difficulties. Once an appropriate descriptive assessment has been performed, it is important to explain to the child the nature of the dysfunction while delineating the child's strengths. This explanation should be provided in nontechnical language, communicating a sense of optimism and a desire to be helpful and supportive.

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Bypass Strategies (Accommodations)

Numerous techniques can enable a child to circumvent neurodevelopmental dysfunctions. Such bypass strategies are ordinarily used in the regular classroom. Examples of bypass strategies include using a calculator while solving mathematical problems, writing essays with a word processor, presenting oral instead of written reports, solving fewer mathematical problems, being seated near the teacher to minimize distraction, presenting correctly solved mathematical problems visually, and taking standardized tests untimed. These bypass strategies do not cure neurodevelopmental dysfunctions, but they minimize their academic and nonacademic effects and can provide a scaffold for more successful academic achievement.



Interventions (Remediation of Skills)

Interventions can be implemented at home and in school to strengthen the weak links in academic skills. Reading specialists, mathematics tutors, and other such professionals can use diagnostic data to select techniques that use a student's neurodevelopmental strengths in an effort to improve decoding skills, writing ability, or mathematical computation skills. Remediation need not focus exclusively on specific academic areas. Many students need assistance in acquiring study skills, cognitive strategies, and productive organizational habits.

Early identification is critical so that appropriate instructional interventions can be introduced in an effort to minimize the long-term effects of academic disorders. Any interventions should be empirically supported (e.g., phonologically based reading intervention has been shown to significantly improve reading skills in school-age children). Remediation may take place in a resource room or learning center at school and is usually limited to children who have met the educational criteria for special education resource services as described earlier.

Interventions that can be implemented at home could include drills to aid the automatization of subskills, such as arithmetic facts or letter formations, or the use of phonologically based reading programs.

There are a number of treatment/intervention approaches to strengthening executive function that have demonstrated positive findings. These include computerized training programs such as CogMed (Pearson) that has been demonstrated to strengthen working memory skills in children via a computer game model. Curriculum-based classroom programs, such as the Tools of the Mind (Tools) and PATHS (Promoting Alternative Thinking Strategies) also have accumulating research support. These programs employ approaches such as social play and target areas such as self-control and problem-solving to teach and strengthen executive functions. Aerobic exercise and martial arts such as Tae Kwon Do, which stresses discipline and emphasizes the development of self-regulation (e.g., impulse control), have demonstrated improvements that generalize in many aspects of executive functions and attention.



Developmental Therapy

Controversy exists about the efficacy of treatments to enhance weak developmental functions. Nevertheless, some forms of developmental therapy are widely accepted. Speech-language pathologists commonly offer intervention for children with various forms of language disability. Occupational therapists strive to improve the motor skills of certain students with writing problems, and physical therapists address gross motor clumsiness.



Curriculum Modifications

Many children with neurodevelopmental dysfunctions require alterations in the school curriculum to succeed, especially as they progress through secondary school. Students with memory weaknesses might need to have their

courses selected for them so that they do not have an inordinate cumulative memory load in any single semester. The timing of foreign language learning, the selection of a mathematics curriculum, and the choice of science courses are critical issues for many of these struggling adolescents.



Strengthening of Strengths

Affected children need to have their affinities, potentials, and talents identified clearly and exploited widely. It is as important to augment strengths as it is to attempt to remedy deficiencies. Athletic skills, artistic inclinations, creative talents, and mechanical abilities are among the potential assets of certain students who are underachieving academically. Parents and school personnel need to create opportunities for such students to build on these assets and to achieve respect and praise for their efforts. These well-developed personal assets can ultimately have implications for the transition into young adulthood, including career or college selection.



Individual and Family Counseling

When academic difficulties are complicated by family problems or identifiable psychiatric disorders, psychotherapy may be indicated. Clinical psychologists or child psychiatrists may offer long- or short-term therapy. Such intervention may involve the child alone or the entire family. Cognitive-behavioral therapy is a technique that is increasingly popular. It is essential that the therapist have a firm understanding of the nature of a child's neurodevelopmental dysfunctions.



Controversial Therapies

A variety of treatment methods for neurodevelopmental dysfunctions have been proposed that currently have no known scientific evidence base of efficacy. This list includes dietary interventions (vitamins, elimination of food additives or potential allergens), neuromotor programs or medications to address vestibular dysfunction, eye exercises, filters, tinted lenses, and various technologic devices. Parents should be cautioned against expending the excessive amounts of time and financial resources usually demanded by these remedies. In many cases, it is difficult to distinguish the nonspecific beneficial effects of increased support and attention paid to the child from the supposed target effects of the intervention.



Medication

Psychopharmacologic agents may be especially helpful in lessening the toll of neurodevelopmental dysfunctions. Most commonly, stimulant medications are used in the treatment of children with attention deficits. Although most children with attention deficits have other associated dysfunctions (such as language disorders, memory problems, motor weaknesses, or social skill deficits), medications such as methylphenidate, dextroamphetamine, lisdexamfetamine, mixed amphetamine salts, and atomoxetine can be important adjuncts to treatment by helping some children focus more selectively and control their impulsivity. When depression or excessive anxiety is a significant component of the clinical picture, antidepressants or anti-anxiety drugs may be helpful. Other drugs may improve behavioral control (see [Chapter 21 \(#/content/3-s2.0-B9781455775668000211?scrollTo=%23c00021\)](#)). Children receiving medication need regular follow-up visits that include a history to check for side effects, a review of current behavioral checklists, a complete physical examination, and appropriate modifications of the medication dose. Periodic trials off medication are recommended to establish whether the medication is still necessary.

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