Joint Technical Report—Learning Disabilities, Dyslexia, and Vision

abstract

FREE

Learning disabilities constitute a diverse group of disorders in which children who generally possess at least average intelligence have problems processing information or generating output. Their etiologies are multifactorial and reflect genetic influences and dysfunction of brain systems. Reading disability, or dyslexia, is the most common learning disability. It is a receptive language-based learning disability that is characterized by difficulties with decoding, fluent word recognition, rapid automatic naming, and/or reading-comprehension skills. These difficulties typically result from a deficit in the phonologic component of language that makes it difficult to use the alphabetic code to decode the written word. Early recognition and referral to qualified professionals for evidence-based evaluations and treatments are necessary to achieve the best possible outcome. Because dyslexia is a language-based disorder, treatment should be directed at this etiology. Remedial programs should include specific instruction in decoding, fluency training, vocabulary, and comprehension. Most programs include daily intensive individualized instruction that explicitly teaches phonemic awareness and the application of phonics. Vision problems can interfere with the process of reading, but children with dyslexia or related learning disabilities have the same visual function and ocular health as children without such conditions. Currently, there is inadequate scientific evidence to support the view that subtle eye or visual problems cause or increase the severity of learning disabilities. Because they are difficult for the public to understand and for educators to treat, learning disabilities have spawned a wide variety of scientifically unsupported vision-based diagnostic and treatment procedures. Scientific evidence does not support the claims that visual training, muscle exercises, ocular pursuit-and-tracking exercises, behavioral/perceptual vision therapy, "training" glasses, prisms, and colored lenses and filters are effective direct or indirect treatments for learning disabilities. There is no valid evidence that children who participate in vision therapy are more responsive to educational instruction than children who do not participate. *Pediatrics* 2011;127:e818–e856

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KEY WORDS

learning disabilities, vision, dyslexia, ophthalmology, eye examination, vision therapy

ABBREVIATIONS

ADHD—attention-deficit/hyperactivity disorder
IDEA—Individuals With Disabilities Education Act
ADA—Americans With Disabilities Act
IEP—individualized education plan
EBM—evidence-based medicine
SSS—scotopic sensitivity syndrome

The guidance in this report does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

This technical report supports the joint policy statement from the American Academy of Pediatrics, American Academy of Ophthalmology, American Academy of Pediatric Ophthalmology and Strabismus, and American Association of Certified Orthoptists titled "Learning Disabilities, Dyslexia, and Vision," which is available at www.aap.org (direct link: www.aappolicy.org/cgi/reprint/pediatrics;124/2/837.pdf) and www.aao.org(direct link: www.aao.org/about/policy/upload/Learning-Disabilities-Dyslexia-Vision-2009.pdf).

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INTRODUCTION

Reading is the complex process of extracting meaning from abstract written symbols. In modern societies, reading is the most important way to access information, and in today's Western society, literacy is a prerequisite for success. In elementary school, a large amount of time and effort is devoted to the complicated process of learning to read. Because of the difficulties encountered in teaching some children to read, Congress mandated that the Eunice Kennedy Shriver National

Institute of Child Health and Human Development assemble a national panel of educators and scientists to research the optimal methods of teaching children to read. The 2000 report of the National Reading Panel, titled *Teaching Children to Read: An Evidence-Based Assessment of the Scientific Research Literature on Reading and Its Implications for Reading Instruction*,[1] linked research findings with recommendations for specific approaches to teaching reading to all children. The panel concluded that existing evidence supported early explicit instruction in phonemic awareness, phonics-based reading programs, and guided oral reading to improve fluency.

Learning disabilities may interfere with children reaching their full potential. The inability to read and comprehend is a major obstacle to learning that may have long-term educational, social, and economic implications. Teaching children with reading difficulties is a challenge for the student, parents, and educators. Therefore, the causes and treatment of reading disorders have been the subject of considerable thought and study.

This report discusses how we learn to read, the phonologic model, the recognition and treatment of reading difficulties, visual function and reading, the magnocellular deficit theory, colored lenses and overlays, vision therapy, and the roles of the pediatrician and ophthalmologist.

BACKGROUND

History

In 1877, Kussmal[2,3] first described a case of acquired word blindness in an adult alexic patient with a parietal lobe lesion. Hinshelwood,[2,4] an ophthalmologist from Scotland, studied and described an adult with word blindness in 1895. In 1903, an autopsy of this patient revealed abnormalities in the left angular gyrus immediately posterior to Wernicke's area.[4] Morgan,[2,5] a general practitioner from England, published the first case of a child with congenital word blindness in 1896. Subsequently, Hinshelwood turned his attention to both congenital and acquired word blindness. He credited the term "dyslexia" to Berlin.[6] In 1917, he highlighted the potentially inherited aspect of reading disability. Hinshelwood estimated that 1 in 1000 students in elementary schools might have word blindness and postulated that the primary disability was in visual memory for words and letters. He strongly advocated intensive, individualized personal instruction.[2,4]

Beginning in the 1920s, Orton,[2,7,8] a neuropsychiatrist, demonstrated a hereditary component for reading disabilities in children. His studies led to an expanded definition of reading disabilities that was much broader than Hinshelwood's and included a graded series of all degrees of severity of disability. This more liberal definition increased the presumed prevalence to more than 10% of schoolchildren. IQ testing revealed that these children scored near or above average. In 1925, Orton attributed dyslexia to a problem in the visual system, which suggests that an apparent dysfunction from "mixed cerebral dominance" caused problems in visual perception and visual memory, characterized by perception of letters and words in reverse.

The theory that visual dysfunction caused dyslexia led to a proliferation of training programs developed for visual-perceptual and/or visual-motor disabilities. In the 1960s, those prominent in developing and promoting these programs included Kephart, Frostig, Getman, Barsch, Dorman, and Delacato. Research into the programs revealed that, although these programs were sometimes effective in improving perceptual and/or perceptual-motor development, they were ineffective in improving academic performance.[9–12] Although the use of perceptual and perceptual-motor training by educators persisted for a time, by the mid-1980s its use had waned considerably.

Attempts at improved understanding of dyslexia led to the rejection of the visual theories. This process began with a series of related studies that systematically evaluated traditional and widely accepted etiologic conceptualizations, such as Orton's optical reversibility theory,[7] Hermann's spatial confusion theory,[13] and other theories that implicated deficits in visual processes, such as visualization, visual sequencing, and visual memory, as basic causes of reading difficulties.[14,15]

Although Orton attributed dyslexia to visual dysfunction, he was the first to advocate intensive phonics instruction, sound-blending, and multisensory training.[2,8] Orton's work served as the stimulus for Gillingham and Stillman,[16] who also emphasized multisensory training. Subsequently, the Orton-Gillingham phonics techniques have served as the basis for many remediation programs. The International Dyslexia Society, formerly the Orton Dyslexia Society, provides information and resources to professionals and parents regarding reading disabilities.

Learning Disabilities

Learning disabilities constitute a diverse group of disorders in which children who generally possess at least average intelligence have problems processing information or generating output. Learning disabilities can affect neurocognitive processes and may manifest as an imperfect ability to listen, speak, read, spell, write, reason, concentrate, solve mathematical problems, or organize information. Some children may have associated difficulties with motor coordination. Learning difficulties can be associated with and complicated by attention-deficit/hyperactivity disorder (ADHD),[17,18] oppositional defiant disorder, obsessive compulsive disorder, anxiety, or depression.[19] Problems in self-regulatory behaviors, social perception, and social interaction may exist with learning disabilities but do not, by themselves, constitute a learning disability. Although learning disabilities may occur concomitantly with other disabilities (eg, sensory impairment, intellectual disability, serious emotional disturbance) or with extrinsic influences (eg, cultural differences, insufficient or inappropriate instruction), they are not the result of those conditions or influences.[20] Results of recent studies suggest that approximately 20% of the population has some degree of a learning disability.[21] In 2007, 2.7 million public school students (5.5% of all students in public schools) were identified as having learning disabilities and were eligible to receive educational assistance under the Individuals With Disabilities Education Act (IDEA).[22]

Specific learning disabilities include dyslexia (reading disability), dysgraphia (writing disability), and dyscalculia (mathematics disability). Although not included in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*[23] as a specific learning disability, nonverbal learning disability comprises difficulties with social interactions, interpersonal skills, nonverbal problem-solving, visuospatial skills, motor skills, reading comprehension, and mathematics and often coexists with strengths in verbal skills and with fluent and accurate reading.[23] Autism spectrum disorder, although not a specific learning disability, certainly affects learning, because people with autism have difficulties with verbal and nonverbal communication, social interactions, and motor function and may show inappropriate response to sensory information.[23]

Dyslexia

Difficulties in reading are found in a diverse group of conditions that include dyslexia and secondary forms of reading difficulties caused by visual or hearing disorders, intellectual disability, experiential and/or instructional deficits, and other problems.[14,24–26] Dyslexia is defined as a primary reading disorder that is separate from secondary forms.[14,24–26] The terms "specific reading disability," "reading disability," "reading disorder," and "dyslexia" are often used interchangeably in the literature.[14] The term "dyslexia" is derived from Greek and means "difficulty with reading words." Dyslexia is often unexpected in relation to the child's other cognitive abilities. It is a receptive language-based learning disability that is characterized by difficulties with decoding, fluent word recognition, and/or reading-comprehension skills. These difficulties typically result from a deficit in the phonologic component of language that makes it difficult to use the alphabetic code to decode the written word. Secondary consequences may include reduced reading experience that can impede growth of vocabulary, written expression, and background knowledge.[27] A common misconception is that dyslexia is a problem of letter or word reversals. Reversals of letters or words and mirror writing occur normally in early readers and writers. Children with dyslexia are not unusually prone to reversals. Although they do occur, reversal of letters or words, or mirror writing, is not included in the definition of dyslexia.[14,28,29] People with dyslexia may be very creative and bright. In many cases, their high-level thinking is unaffected, and they may be gifted in mathematics, science, the arts, or even in unexpected areas such as writing.[28] People with dyslexia read slowly, but not all people who read slowly have dyslexia.

Approximately 80% of people with learning disabilities have dyslexia, which makes it the most common learning disability.[24,25,30–35] Depending on the definition chosen, the prevalence of reading disability is approximately 5% to 20% of school-aged children in the United States.[21,24,31,34] Reading disabilities seem to affect males slightly more than females,[36–38] although schools identify boys with them twice as often as girls.[22,31] Both environmental and genetic influences affect the expression of dyslexia.[39] Dyslexia has been identified as having a strong genetic basis.[14,24–26,30,31,40,41] Approximately 40% of siblings, children, or parents of an affected person will have dyslexia. Although dyslexia may be inherited, it may also exist in the absence of a family history. Results of family and twin studies have suggested that 50% of the problems in performance can be accounted for by heritable factors; environmental influences are greater in children with lower IQ scores.[42]

Reading ability and reading disability occur along a continuum; reading disability is represented within the lower tail of a normal bell-shaped distribution of reading ability.[21] The lower tail is actually composed of reading difficulties from both primary dyslexia and secondary causes. Dyslexia is a lifelong condition that varies in degrees of severity. Most children with reading disabilities have relatively mild reading disabilities, and a smaller number of them have more severe reading disabilities.[21,30] Because reading skills occur on a continuum with no clear distinction between typical readers and readers with dyslexia, some experts assert that the term "dyslexia" should be reserved for the 2% to 5% with the most severe reading deficits.[43]

Dyslexia occurs at all levels of intelligence and is a persistent problem that does not represent a transient developmental lag.* Children with poor oral language skills in kindergarten often become poor readers. Over time, good readers and poor readers without intervention tend to maintain their relative positions along the spectrum of reading ability. Children who get off to a poor start in reading rarely catch up on their own. A poor reader in 1st grade will almost invariably stay a poor reader; more than 88% of these children display similar difficulties at the end of 4th grade.[35,44,50] Seventy-four percent of those children identified in 3rd grade as reading disabled will remain so in the 10th grade.[30,34,43,51] Readers with dyslexia must expend more attention, concentration, and energy on the task, which makes reading unpleasant, tiring, and difficult.[39] Students who cannot read well read less. Lost practice opportunities make it difficult to acquire even average levels of reading fluency. Both inaccurate reading and diminished reading practice cause slow growth of fluent word-identification skills and vocabulary growth. The vocabularies and concept knowledge of children who read less will plateau as their reading peers improve.[52] The consequences of a slow start in reading become monumental as they accumulate exponentially over time.[35] In the later grades, when children switch from learning to read to reading to learn, reading-impaired children are prevented from fully exploring science, history, literature, mathematics, and the wealth of information that is presented in print. With interventions, people with dyslexia may learn to read accurately, but they have a persistent problem with fluency and continue to read slowly and not automatically throughout their lives.[39] The fluency deficit is problematic for older children, who are expected to read increasingly sophisticated texts.[53]

Many children with reading disability are observed to grow ashamed as they struggle with skills that their classmates master easily. This shame may cause a loss of motivation to learn to read that can further compound the situation. Untreated or poorly treated dyslexia may lead to frustration, low self-confidence, and poor self-esteem, which substantially increases the risk of developing psychological and emotional problems.[19,30]

Approximately 15% of students with reading disability also have ADHD, whereas approximately 35% of students with disorders of attention also have reading disability.[19,24,30,54] However, the 2 disorders are distinct and separable.

Dysgraphia is a learning disability that affects writing abilities. Disorders of written expression can manifest themselves as difficulty with spelling and problems putting thoughts on paper. The spelling deficits in dysgraphia may be oral and/or written. Dysgraphia can also manifest itself as difficulty with writing motor coordination or poor handwriting. Dysgraphia is the learning disability that most frequently co-occurs with dyslexia because of their directly related phonemic base. Decoding breaks the code receptively and encoding (spelling) puts it back together expressively.

Phonologic Model

Currently, the most accepted model for the acquisition of the ability to read is the phonologic model. Phonologic awareness is the sensitivity to the sound structure of oral speech and phonemic awareness is the understanding that speech can be segmented or broken into individual sounds that signal differences in meaning, whereas phonics is the understanding that segmented units of speech can be represented by printed forms.[55] Phonologic awareness is the basis for scaffolding written language onto oral language.[55]

Phonemes are the speech sounds that enable us to tell 1 word from another. For example, "pet" and "bet" are distinguished by the sounds of their initial consonant; thus, changing the "p" to "b" changes the meaning of the word.[56] Coarticulation is the merging and overlapping of sounds into a sound "bundle," which makes oral communication much more efficient.[55] To make normal conversation possible, 8 to 10 phonemes per second are strung together and blended so thoroughly that it is often impossible to separate them. A written word like "cat" has 3 letter-sound units, although the ear hears only 1 sound, not 3, when the word "cat" is spoken aloud.

Oral language development has been found to play a critical role in learning to read.[1,35,57–59] Oral language acquisition is preprogrammed into human development; a drive for expression through organized vocalization seems innate to infant development, although specific languages need to be acquired. On the other hand, writing, an artificially designed use of abstract symbols to represent language, is an acquired skill.[34] English uses an alphabetic system in which each letter is a symbol that is an abstract building block of that language's phonemes (sounds). English is a phonemically complex language in which the 26 letters of the alphabet create 44 sounds or phonemes in approximately 70 letter combinations.[32,33,60] The phonemic complexity of a language corresponds to the prevalence of dyslexia, which points to the linguistic origin of dyslexia.[14,29] Manifestations of dyslexia are often worse in English because of the greater number of inconsistencies and exceptions within the English lan-

*Refs 14, 20, 24–26, 28–31, 34, 35, and 44–49.

guage, but dyslexia is confined neither to the United States nor to English speakers.[14]

Learning to read and write is a complex process that requires active learning. Reading is more difficult than speaking, because children must be aware of the sound structure in spoken language and then break the alphabetic code to acquire the sound/symbol connection. Developing this awareness is not automatic, because phonemes are not separated in speech. To decode a written word, the sounds must be broken apart. Unless the child can convert the printed characters into the phonetic code, these letters remain a mystery of lines and circles that are devoid of linguistic meaning.[34] According to Moats[61] and the American Federation of Teachers, teaching reading is rocket science!

Reading comprises decoding, fluency, and comprehension and requires adequate memory and sustained attention. The foundation for reading is decoding. Decoding, or word attack, is the ability to sound out words. Poor decoding is the core characteristic of poor reading. Most people with dyslexia have a neurobiological deficit in the processing of the sound structure of language, called a phonemic deficit, which impairs decoding and prevents word identification.† The ability to learn to decode print is determined primarily by phonologic skills such as phonologic awareness, facility in alphabetic mapping, name encoding and retrieval, and verbal memory.[14] The reader with dyslexia experiences difficulty in decoding and identifying words because of a specific impairment in the neural representation, storage, retrieval, and coding of phonemes.‡ Children with dyslexia often experience even more difficulty with spelling (dysgraphia) because of imperfectly stored representations of words, although not all children with poor spelling skills have dyslexia.

Children with more severe forms of dyslexia may have a second deficit in rapid automatic naming that causes slow naming of letters, numbers, and pictures, which creates a double deficit.[14,31,66–69] Other children with severe forms of dyslexia may have problems with their short-term working memory or attention or an additional comprehension deficit.[70] Some children with reading difficulties also experience a deficit in orthographic skills, which are defined as difficulties with letter/number orientation recognition and memory, although these skills may improve with development.[14,71]

A child must first accurately decode a word before it can be read fluently. Fluency is the ability to read connected text with expression rapidly, smoothly, effortlessly, and automatically with little conscious attention to decoding. An inexperienced reader will use the phonetic method to sound out most words and consequently will read slowly. No fluent reader uses phonics routinely. Poor decoders are stuck on the task of trying to sound out words to make sense of the text.[52] The next task for the beginning reader is to move from the early phases of "sounding out" words to the more skilled phase in which word recognition occurs almost instantly. Word recognition is the ability to read words without sounding them out.[52] Experienced readers use the whole-word method and will quickly recognize most words as individual units. Average readers require 4 to 14 exposures to a word before it becomes a sight word,[32,33] whereas students with learning disabilities may need up to 40 exposures.[33,72] Fluent reading requires automatic phonemic decoding and word recognition.[1,24,25,31–34,64] Although the ability to read words accurately is a necessary skill, reading speed and fluency become critical factors in ensuring that children gain comprehension. Fluency forms the bridge between decoding and comprehension.[34]

Comprehension is impaired without efficient automatic word-recognition skills.[55] If reading is slow and labored because of decoding difficulties and requires a large portion of their available conscious attention, children do not have enough attentional capacity and cognitive energy to remember what they have read, much less relate the ideas to their own background knowledge.[32–34,64] Current theory maintains that the deficit in lower-order phonologic linguistic decoding function blocks access to the usually intact higher-order cognitive and linguistic functions.[15,24,25,30–35] Thus, it is difficult to apply general intelligence and reasoning, vocabulary, and syntax to the reading endeavor to obtain comprehension.[24,25,34] In some cases, however, other children can show comprehension difficulties in the absence of word-recognition problems. Vocabulary acquisition in a child with dyslexia often may not keep pace with that of a child's peers, because the less a child reads, the fewer the new words to which the child is exposed. In addition to decoding deficiencies, inadequate vocabulary, verbal reasoning, attention, memory, and limitations in background knowledge also can cause reading-comprehension difficulties. Thus, any or all of these problems can interfere with the ultimate purpose of reading, which is comprehension.[34]

Neurobiology

Dyslexia is currently believed to be neurobiological in origin, which means that the problem is located physically in the brain. There is strong scientific evidence that supports the neurobiological basis for the phonologic-coding–

†Refs 1, 14, 15, 20, 24–26, 30–35, 43, 46–49, 55, 60, and 62–65.

‡Refs 1, 24, 25, 31–34, 39, 46–49, and 64.

deficit theory of dyslexia.§ Both anatomical and brain-imagery studies have revealed differences in the way the brain of a person with dyslexia develops and functions. Neuroanatomical changes, microarchitectural distortion, and MRI findings in language-related areas have been observed in the brains of patients with dyslexia, including the absence of the normal asymmetry in the language areas of the brain and similar volume in the left and right planum temporale; normally, the left planum temporale is larger.[86–88] Functional MRI and positron emission tomography (PET) scans measure changes in metabolic activity and blood flow during cognitive tasks in specific brain regions. In typical readers, functional MRI and PET-scan studies have shown that reading takes place predominantly in left-hemisphere sites including the inferior frontal (Broca) area, which is associated with articulation, naming, and silent reading; 2 areas in the posterior brain regions—the parietal temporal region, which serves word analysis, and the left occipitotemporal area, which is involved in word-form and fluent reading; and the posterior inferior temporal cortex, which is associated with lexical retrieval. Children with dyslexia, on the other hand, use different areas of the brain when reading.‖ People with dyslexia have demonstrated a dysfunction in the left-hemisphere posterior reading systems and have shown compensatory use of the inferior frontal gyri of both hemispheres and the right occipitotemporal word-form area.¶ These studies have demonstrated that dyslexia is an abnormality in the word-analysis pathways of the brain that interferes with its ability to convert written words into spoken words. It is postulated that this abnormality is causal, not a result of poor reading experience. Functional MRI studies have also shown brain plasticity in that the dyslexia-specific brain-activation profile improves after successful evidence-based phonologic remedial intervention.[48,80,85]

White-matter abnormalities have also been detected in association with dyslexia. In people with dyslexia, white-matter organization seems to be weaker in the left posterior brain region and seems to project too weakly within the primary reading pathways of the linguistic left hemisphere and too strongly between hemispheres.[53] White-matter pathways of the brain may be characterized by diffusion tensor imaging that provides a quantitative index of the organization of large myelinated axons that constitute the long-range connections of brain networks. Young children are able to undergo diffusion tensor imaging.

Recent genetic-linkage studies have identified many loci at which dyslexia-related genes are encoded. Four candidate genes have been implicated in neural migration, axonal growth, and brain development.[89] These brain changes seem to cause phonologic and auditory processing abnormalities.[89]

RECOGNITION AND TREATMENT

Dyslexia is a disorder that affects people of all ages, but its symptom profile changes over time.[81,90] Because dyslexia is both familial and heritable, affected younger siblings can often be identified earlier. A child should be observed for early indications of dyslexia if he or she has a family history of learning disabilities or has a history of other factors that may be predictive of learning disabilities including hearing, language, or speech problems; preterm birth; low birth weight; fetal exposure to drugs or alcohol; infections of the central nervous system; severe head injuries; cognitive difficulties; or developmental delay.[28] An early history of language difficulties such as delay or difficulty in developing speech and language, learning rhymes, or recognizing letters and sound/symbol connections, may be an early indication of dyslexia.[14,24,34,35,58,62,81] Parents or teachers may detect early warning signs of learning difficulties in preschool-aged children, and early evaluation and intervention should be considered. It is not in the child's best interest to "wait and see" or hope that the child will "grow out of" his or her problems.[91]

However, in many cases, learning disabilities are not discovered until children experience academic difficulties in elementary school.[24,25,34,81] Many parents who had noticed that their child was exhibiting learning difficulties waited a year or more before acknowledging that their child might have a problem and seeking assistance. In elementary school, a child with reading disabilities may show difficulty with remembering words, reading, spelling, handwriting, or writing speed. Teachers are in a position to identify reading problems before they progress significantly. Early identification of children in early grades who are showing delays or difficulties should be a high priority for elementary school teachers. Teachers need to have a strong understanding of the result of research in reading theory and practice to become well versed in reading development and assessment.[33] At all grade levels, teachers must understand the course and the role of instruction in optimizing literacy development. After initial school interventions have been unsuccessful, evaluation for learning disabilities should be considered for all children who present with school diffi-

§Refs 14, 24, 25, 30–35, 39, 40, 43, 46, 48, 49, 66, and 73–85.

‖Refs 14, 24, 25, 30, 31, 34, 39, 40, 46, 48, 49, 66, and 73–85.

¶Refs 24, 25, 30, 31, 34, 40, 46, 48, 49, 66, and 73–85.

culties, even if reading difficulty is not the chief complaint.[34]

Parents should read aloud to their children to help develop language skills beginning as early as 6 months of age.[92] Educational experts indicate that reading aloud to children is the single most important activity for parents and caregivers to do to prepare children to learn to read.[33,35] Comprehensive beginning reading instruction is the best educational prevention for reading problems.

The best current approach to the problem of reading failure is to allocate resources for prevention and early identification. The beneficial effects of early identification and intervention are apparent in many studies.[35] In the elementary grades, reading screening should be performed yearly and early in the school year. Assessments for difficulties with alphabet recognition, phonemic awareness and rapid naming in kindergarten,[57,93] adding word identification fluency in 1st grade, and adding oral reading fluency in 2nd grade can predict many of those who will have difficulty learning to read.# Prevention and early phonologic awareness intervention programs in kindergarten through 2nd grade can increase reading skills in many poor readers to average reading levels. Torgesen reviewed many studies on early intervention and found that when intervention began in the 1st grade, the expected incidence of reading disability of 12% to 18% was reduced substantially to 1.6% to 6%.[94] If reading-impaired children receive effective phonologic training in kindergarten and 1st grade, they will have significantly fewer problems in learning to read on grade level than do children who are not identified or helped until 3rd grade.** Children identified as reading disabled after 2nd grade rarely catch up to their peers.[43] Waiting for failure decreases the chances of interventional success. Results of longitudinal studies have shown that when intervention is delayed until 3rd grade or 9 years of age (the average age at which these children receive services), then approximately 74% of these children will continue to have difficulties learning to read through high school.[30,34,43,51] Gains are maintained for at least 1 or 2 years by approximately 50% of children after they return to the school's standard curriculum. These children who retain their benefits improve from year to year, but they do not further catch up to typical readers.[53]

Dyslexia is most often identified in the primary grades, but it is not diagnosed in some students until later during middle or high school, when more complex reading and writing skills are required. In early elementary school, some children compensate by using other strengths until the educational demands increase and make the reading disability more evident. Reading problems diagnosed in the 4th grade or beyond may be secondary to poor word recognition, a combination of poor word recognition and poor comprehension skills, or solely attributable to poor comprehension skills. Late emerging reading disabilities often go undetected in schools. Approximately 10% of children with dyslexia have good word-reading skills but have poor listening and reading-comprehension skills. Poor comprehension skills are often attributable to working-memory, semantic, and syntactic difficulties. Deficits in phonologic coding continue to characterize readers with dyslexia even in adolescence and adulthood.[34] Older children and adults may learn to read words accurately, but they will not be as fluent or automatic, which results in a slower reading rate.†† Although older children and adults can be taught to read, the time and expense of doing so is enormous.[34] Poor comprehension skills also persist and will impair the ability to learn in general.

Difficulties in early reading may be caused by experiential and instructional deficits in addition to primary dyslexia. Some children enter school with experiential deficits in oral language skills and general knowledge as well as delayed phonologic skills.[35] Experiential risk factors include being raised in a high-poverty environment or in a home in which English is the second language or having limited exposure to oral or written language. It is important to recognize these children, differentiate them from children with true dyslexia, and provide proper remediation for them.

The IDEA, Section 504 of the Rehabilitation Act, and the Americans With Disabilities Act (ADA) define the rights of students with dyslexia and other specific learning disabilities.[95–98] The IDEA defines a child with a disability as someone who has any of 13 disabling conditions, including learning disabilities, and who need special education and related services because of the disability. The IDEA guarantees each child a free, appropriate public education tailored to his or her individual needs and allows parents to request a formal educational evaluation by the school district to determine if a child has a disability and qualifies for special education and related services. It allows parental access to all meetings and paperwork, transition planning, and related services. The IDEA also provides funding for special education services.[96] People with a physical or mental impairment that substantially restricts 1 or more major life activities are eligible for services under Section

#Refs 1, 14, 20, 24, 30, 32–35, 43, 55, 58, 60, 64, 65, and 93.

**Refs 1, 14, 19, 32, 33, 35, 41, 43, 47, 54, 60, 64, 65, 88, 90, and 95.

††Refs 14, 24, 25, 34, 35, 39, 54, 60, and 65.

504 of the Rehabilitation Act of 1973.[97] This act protects the civil rights of students with disabilities and attempts to remove barriers to allow them to participate freely. Students who do not have 1 of the 13 included disabilities or meet the severity criteria but still require some assistance to be able to participate fully in school may be a candidate for a Section 504 plan. Some schools use Section 504 to support learning-disabled students who need only accommodations. Children with ADHD who do not need more comprehensive special education support also are frequently served under this law. The ADA protects people who have a physical or mental impairment that restricts 1 or more major life activities from discrimination. Because learning is considered such an activity under the ADA, students served under the IDEA also are covered by this law.[99] Congress recently passed the ADA Amendments Act of 2008, which became effective in 2009. It expanded the list of major life activities to include reading, thinking, and concentrating.[99] As a result, more people with learning disabilities are now able to satisfy the definition of disability, gain access to reasonable accommodations, and be protected from discrimination.

The latest revision of the IDEA, the federal law that governs special education, offers 2 approaches that can be used in the young underachieving child.[14] The first method is called the response-to-intervention (RTI) method and is designed primarily for the elementary school grades. RTI is a multitiered approach to the early identification and support of students with learning and behavior needs. The RTI process begins with high-quality instruction and screening of all children in kindergarten to identify any child who exhibits the early signs of potential reading difficulties. In the RTI method, the child will be placed directly in an educational intervention program when he or she first experiences academic difficulties. Struggling learners are provided with interventions at increasing levels of intensity to accelerate their rate of learning. The individual student's progress is closely monitored to assess both the learning rate and level of performance. Educational decisions about the intensity and duration of interventions are based on the individual student's response to instruction. Only the children who do not show significant improvement with the first-tier group intervention program and the second-tier targeted intense individual intervention program will undergo a full diagnostic educational assessment.[14,100,101] The majority of these students undergoing educational assessment will likely be identified as reading disabled and qualify for special education services. Ideally, this approach will allow earlier and more effective identification and treatment than the traditional method in which the child must show persistent poor academic achievement for a few years before referral, assessment, and remediation. A "wait-to-fail" situation can occur when an ability-achievement discrepancy formula is used to determine if a student qualifies for a formal diagnostic assessment for a learning disability.[35,43,65,100,101] Thus, the student has suffered the academic and emotional strains of failure for 2 to 3 years before potentially effective instruction can begin.

At all ages, dyslexia is a clinical diagnosis.[81] A formal evaluation is needed to discover whether a person has a learning disability. The assessment techniques should be evidence based.[102,103] Although many schools still use a discrepancy formula to qualify students for special education, there is an emerging consensus among researchers and clinicians that the dependence on a discrepancy between IQ and reading achievement for a diagnosis of dyslexia has outlived its usefulness except in limited circumstances.[34,44,104] There is no single standardized test used to make the diagnosis of dyslexia. Because the hallmark of dyslexia is the presence of a phonologic deficit in the context of relatively intact overall language abilities, the diagnosis of dyslexia can be far more specific.[34] Indicators of phonologic difficulties can be detected by a child's history, by observation, and/or by specific tests. Furthermore, dyslexia is not diagnosed with testing in the areas of vision, sensory-motor skill, or auditory processing, and it is not determined solely by medical screening or psychological/IQ testing alone.[105]

A comprehensive evaluation is necessary to determine the appropriate diagnosis for children who present with reading weaknesses. Comprehensive evaluation in all areas of the suspect disability should be conducted. Such evaluation is multifaceted and generally involves interviews with the child and family; questionnaires and rating scales completed by parents, teachers, and the student; social, developmental, medical, and educational histories; observation of the child in the classroom; and evaluation of test data.[26] The testing can be conducted by trained school or outside specialists. The composition of testing by a school psychologist varies according to state and school district. An evaluation by a developmental/behavioral pediatrician, school psychologist, educational psychologist, clinical psychologist with special training in learning assessments, or neuropsychologist consists of a battery of tests that will provide information on a child's overall abilities, particularly learning style, information-processing abilities, academic skills, and describing areas of strength and weakness. The assessment may include information provided by parents; health and developmental history; knowledge of any previous medical conditions; behavioral rating scales completed by parents, teachers, and, if appropriate, the student; school observations; review of school records; evaluation of intellect, memory, attention, and concentration; perceptual and sensory skills; executive skills; language; academic achievement; motor skills; social-emotional and behavioral components; and adaptive levels. Such an evaluation traditionally has included critical underlying language skills that are closely linked to dyslexia, including receptive-listening skills; expressive-language skills; phonologic skills, including phonemic awareness and rapid naming of letters and names; vocabulary; reading accuracy; fluency; and comprehension. A student's ability to read lists of words in isolation, as well as words in context, should also be assessed. School assessments are usually performed to determine if a child qualifies for special education programs or therapies. These assessments focus on achievement and the skills needed for academic success.

If the focus of the studies is on educational issues as well as on a broader assessment of brain function, the assessment is called a "neuropsychological" evaluation. Neuropsychologists with a special competency in the area of pediatrics can perform extensive evaluations that can lead to a comprehensive understanding of the child's cognitive and emotional processes and provide the gold standard for a learning-disability evaluation. Neuropsychologists can diagnose learning or behavior disorders caused by altered brain function or development. In addition to test data, the assessment also involves a review of the relevant medical, psychiatric, educational, speech-language, occupational therapy, and school-related records (ie, Section 504 plans and individualized education plans [IEPs]). Parents, teachers, and treating professionals are interviewed for their presenting concerns. Neuropsychologists assess intellect, memory, attention and concentration, perceptual and sensory skills, executive skills, language, academic achievement, motor skills, social-emotional and behavioral components, regulatory capacities, adaptive levels, and other neuropsychological phenomena to illuminate the neurocognitive underpinnings of specific learning disabilities as well as their subtypes. This information is critical in identifying the specific deficits relative to the reading weaknesses as well as other comorbid variables that are also involved. These variables can include coexisting attention and concentration disorders, executive-functioning weaknesses, and social-emotional factors (ie, anxiety, depression, and oppositional features). Such information helps to identify whether attentional and/or emotional issues might be contributing to or resulting from learning difficulties.[19] Because neuropsychological evaluation is driven by an understanding of the brain systems involved in different academic functions, it can illuminate learning disorders, allow predictions to be made about future difficulties a child may encounter so that preemptive interventions can be initiated, and bring to light comorbid conditions that may not yet have become apparent. The determination of the underlying causes of the disorder and comorbid conditions will clarify the types of interventions from which the child is most likely to benefit and will provide a road map on which evidence-based interventions and accommodations are based across home and school environments. Referring professionals and parents are provided with a detailed written report of test findings, the diagnosis, treatment recommendations, accommodations, and referral suggestions.

After a comprehensive school evaluation, a learning disability will be diagnosed formally in some students. Under the IDEA, a "child with a disability" is one who is eligible for special education and related services. Eligibility for special education is determined by the IEP team. The evaluation is necessary for developing a proper treatment plan and should also identify the different instructional methods that are most beneficial at various stages of reading development for each child.[55,59,104] To outline the educational goals and services that the student needs to be successful, an IEP contract is developed. The IEP will describe goals and objectives; outline what services will be needed, including specific remedial interventions, accommodations, modifications, and which type of program would be best; and set guidelines to measure future educational progress. After there is agreement by the school professionals and parents, the services that the school system will provide are listed in the IEP. The IEP contract must be signed by the school professionals and parents before it can be implemented. The IEP is reviewed on an annual basis and, if necessary, revised for the next school year. Addendum IEPs can be held if issues in the initial IEP need to be changed or modified during the school year. Every 3 years, the child will undergo comprehensive reevaluation. Alternatively, parents may obtain an independent educational evaluation. If parents obtain an independent educational evaluation on their own and it meets the school's criteria, those results and recommendations must be considered by the IEP team. The IEP team would still need to determine if the disability and its severity qualify to obtain special education and related services in school. Children with less severe disabilities who do not qualify for school services may still benefit from remediation and other therapies outside of school at the parents' expense.

Many struggling students will not show severe enough difficulties on evaluation to receive a diagnosis of a learning disability and will not be eligible for special education and related services. These students still may need targeted reading assistance to be able to participate fully in school and may be a candidate for a Section 504 plan. The evaluation information may be used to decide what educational accommodations may be needed in a regular education program. In that case, a Section 504 plan will be written that describes the areas of difficulty and lists the accommodations that will be provided in the regular classroom.

The diagnosis and treatment of a child who has learning disabilities depend on the ongoing, coordinated collaboration of a multidisciplinary team that may consist of educators, educational remediation specialists, special services, psychologists, and physicians. Speech therapists can evaluate and treat underlying oral language difficulties often associated with dyslexia or help students learn phonemic awareness. Physical and occupational therapists do not treat dyslexia but do treat fine motor, gross motor, balance, proprioceptive, and sensory-processing disorders that may coexist in some children with learning disabilities.[19] A vision specialist for the visually impaired may benefit children with dyslexia who have low vision. Physicians, including general pediatricians, developmental/behavioral pediatricians, family physicians, neurologists, ophthalmologists, otolaryngologists, mental health professionals, and other appropriate medical specialists may assist in diagnosing and treating any associated health problems if they are present in these patients. Clinical psychologists or other mental health providers, including developmental/behavioral and neurodevelopmental pediatricians, can provide strategies to help children better cope with social challenges that may be associated with learning disabilities. Psychiatrists, developmental/behavioral pediatricians, neurodevelopmental pediatricians, or general pediatricians with special expertise may prescribe medications or conduct therapy to improve comorbid psychological disorders.

Treatment for dyslexia consists of using educational tools to enhance the ability to read. Educational therapists or educators who have been specially trained in learning disabilities develop and implement intervention plans for children with learning disabilities and dyslexia. An appropriate treatment plan will focus on strengthening the student's weaknesses while using the strengths. Because many students with learning disabilities receive most of their instruction in general education class, teachers need to be trained on the instructional strategies essential to success for these students.[22] Many children with dyslexia do well in small group instruction of matched students, whereas others need one-on-one help so that they can move forward at their own pace. The instruction must be intensive enough and continue long enough to have a positive effect that will endure.[105] If a student with dyslexia has an outside academic therapist, the therapist should work closely with the child's classroom teachers.

The critical elements for effective intervention include individualization, feedback and guidance, ongoing assessment, and regular ongoing practice.[34] Remediation, educational accommodation, and modification are used as techniques for overcoming dyslexia and the educational deficits that it causes.[24,30,33,34,55,60,63,81] The management of dyslexia demands a lifespan perspective; early on, the focus is on remediation.[34] Remedial interventions should be aimed at the specific needs of the child and viewed as a dynamic process. Because dyslexia is a language-based disorder, treatment should be directed at this etiology.‡‡ Reading instruction should be explicitly taught, which means that children are not expected to infer key skills or knowledge.[34] Students who are easily confused are more likely to be successful when teachers demonstrate and clearly explain what they need to learn.[58] Most children with dyslexia need help from a teacher, tutor, or therapist who has been specially trained in using a multisensory, structured language approach. It is important for these children to be taught by a sequenced systematic and explicit method that involves several senses (hearing, seeing, touching) at the same time.[107] Highly structured daily intensive individualized instruction by an educational therapist or skilled teacher specially trained in explicitly teaching phonemic awareness and the application of phonics is the foundation for remedial programs.§§ In addition, students with dyslexia often need a great deal of structured practice and immediate, corrective feedback to develop automatic word-recognition skills. Remedial programs should include specific instruction in decoding, fluency training, vocabulary, and comprehension.‖‖ The approach to learning decoding begins with detailed instruction in phonemic awareness and then progresses to sound-symbol association (alphabetic principle), phonics, awareness of rhyme, and word segmentation. Phonics is the system of instruction used to teach children

‡‡Refs 1, 14, 24, 25, 30–35, 43, 55, 60, 63–65, 81, and 106.

§§Refs 1, 14, 24, 25, 30–35, 55, 60, and 63–65.

‖‖Refs 1, 14, 32–35, 43, 55, 60, 63–65, and 81.

the connection between letters and sounds. Longitudinal data indicate that systematic phonics instruction results in more favorable outcomes for readers with disabilities than does a context-emphasis (whole-language) approach.¶¶ Later, syllable instruction, morphology, memorization of sight words, spelling, syntax, and semantics are taught.[55] A child must first accurately decode a word before it can be read fluently, but accuracy does not spontaneously evolve into fluency. Sight words need to be memorized, and speeded word-repetition drills should be performed. Daily fluency practice involves repeated guided oral reading of a large amount of text at the child's independent reading level. Practicing reading aloud makes feedback possible. Fluency forms the bridge between decoding and comprehension.[34] Comprehension is gained through fluency training, vocabulary instruction, and active reading comprehension.[34,35] Techniques that enhance active reading comprehension include prediction, summarization, visualization, clarification, critical thinking, making inferences, and drawing conclusions.[14,24,25,33–35,60,63,65] To further gain comprehension, these activities should be combined with other activities to improve language development.[24,25,32–34,55,60,63,64] The brain learns best by practice, and practice is the key to learning to read.

Schools can implement academic accommodations and modifications to help students with dyslexia succeed. Because people with dyslexia have a persistent problem and continue to read slowly throughout their life, it often becomes necessary to adapt the learning environment.[24,25,34,81] Accommodations allow access to higher-level thinking and reasoning strengths. Examples can include preferential seating, extra time for assignments and tests, shortened or modified assignments, help taking notes, lecture notes, computers for writing, a separate quiet room for taking tests, extra assistance using computers, spell checkers, a line guide, or tutors. Reading can be bypassed by using tape recorders, recorded books, text-reading computer programs, lecture tapes, taped tests, or other testing alternatives.[24,25,34,47,81]

Many good software programs currently exist and are affordable. Text-reading software programs provide an excellent opportunity for students with dyslexia to keep up with reading assignments. They are also helpful with written examinations and handouts provided by the teacher. A portable scanner can easily scan written material in the classroom and at home and be used with these programs. The text-reading rate can be adjusted to assist with comprehension, and spaces can be created to write notes in the text. Text-reading software is also designed to be used with writing software to allow a student's writing to be read aloud. The software includes phonetic spelling assistance and intelligent word-prediction features that can address the dysgraphia that often co-occurs with dyslexia. These programs should be a key component of an educational plan, especially for older students. They provide relief, promote self-esteem, and are fun to use. Ongoing appropriate reading remediation should continue along with these compensatory techniques.

Parental participation in a child's education is of utmost importance but may be more difficult if the parents are functionally illiterate. The home is an ideal setting for practice and reinforcement.[34] Children should read aloud to their parents using fun, easy-to-read books. Reading aloud will alert parents if a problem exists. Children who avoid reading are most in need of practice. Parents should help with practice and reinforcement at home with opportunities to check fluency and comprehension via interactive reading experiences. Reading practice at home should be conducted in a supportive and nurturing environment with adequate opportunity for the child to participate in other activities in which he or she excels. As the child gets older, parents should help the child use recommended alternative learning strategies such as books on tape or computers.

Parents should provide ongoing feedback to remediating specialists and should be given the opportunity to ask questions to maximize educational outcomes. Parents need to serve as the child's advocate by speaking with the child's teacher, pediatrician, and other professionals; requesting an educational evaluation; and coordinating remediation and other treatment. By educating themselves in the areas of learning disabilities, available services, and state education rules and regulations, parents will increase their effectiveness as the child's advocate. Parents should work with educators to ensure that the school provides the proper remediation and accommodations and should continue to monitor their child's progress and advocate for their child when necessary.

The teaching of children with dyslexia and learning disabilities is a challenge for educators and parents; however, with proper remediations, educational accommodations, and support, children with dyslexia and learning disabilities can overcome obstacles to improve their reading and writing. Children with extreme deficits in basic reading skills or those with the double deficit of phonologic and rapid automatic naming difficulties are much more difficult to remediate than children with mild or moderate deficits.[30]

¶¶Refs 1, 14, 30, 34, 60, 63, 65, 81, and 106.

The prognosis depends on the severity of the disability; specific patterns of strengths and weaknesses of the individual child; and the appropriateness, amount, intensity, and timing of the intervention.[34] The instruction must be intensive enough and continue long enough to have a positive effect that will endure.[105] Early identification and treatment are the keys to helping children with dyslexia, because children 8 years and younger are more likely to show improvement.

A potential goal in the treatment of dyslexia will be its prevention. Brain measures, such as studies of longitudinal event-related potentials, have shown impressive relations between brain responses at infancy and later language and reading success or failure. In the future, a combination of behavioral and brain measures, perhaps together with genetic and familial information, may enhance the certainty with which dyslexia can be predicted and promote the possibility of preventive intervention that would allow many more children to succeed at learning to read.[53]

ROLE OF THE PEDIATRICIAN AND PRIMARY CARE PHYSICIAN

Pediatricians and primary care physicians can serve a number of important functions for children with dyslexia and their family members. Developmental screening as early as 30 to 48 months may identify language or learning concerns. During well-child visits, physicians should inquire about the child's educational progress and be vigilant in looking for early signs of evolving learning disabilities. General pediatricians should not diagnose learning disabilities but may discuss the possibility with parents.[108] When a child has suspected learning difficulties, the pediatrician or family physician should first assess the child for medical problems that could affect the child's ability to learn and refer him or her for further evaluation if deemed appropriate.[98,108] The physician should take a complete medical history, including determination of maternal drug or alcohol use, neonatal/birth problems, genetic syndromes, and congenital anomalies. Additional medical history should include detection of medical problems (such as chronic or persistent otitis media, asthma, thyroid problems, or any chronic disease that may have caused school absences); neurologic problems (such as seizure disorder, head trauma, history of central nervous system infection, or lead poisoning); developmental, behavioral, emotional, or psychiatric problems (anxiety, depression, obsessive compulsive disorder, or oppositional defiant disorder); ADHD; or autism spectrum disorder. Specific questions on language acquisition and learning should include history of speech delay, speech difficulties, or articulation problems; difficulties in learning letters or phonics; lack of reading readiness; poor instruction; overall academic achievement; and visual difficulties. A family history of speech and language problems, learning disabilities, or functional illiteracy should also be noted. A social history should be taken, and alcohol use, drug use, cultural differences, or poverty for the child or the family should be noted. A complete physical examination to evaluate the child's overall medical and neurologic condition and a psychological, emotional, and behavioral evaluation should be performed. An assessment of the child's activity level, attention span, alertness, cooperation, and ability to communicate should be noted.

Primary sensory impairments should be ruled out by hearing and vision screenings. For all children, primary care physicians should perform hearing and vision screenings according to national standards so that hearing, ocular, and visual disorders are identified as early as possible.[109] Periodic eye and vision screenings can identify most children who have reduced visual acuity or other visual disorders. Vision screening with nonletter symbols may be necessary for testing children with dyslexia or other learning disabilities.[110]

Children who do not pass vision screening should be referred to an ophthalmologist who has experience with the care of children.[109,110] In addition, the recommended routine pediatric vision screenings are unlikely to disclose near-vision problems such as convergence insufficiency, accommodative insufficiency, and significant hyperopia. Children with suspected learning disabilities in whom a vision problem is suspected by the child, parents, physicians, or educators should be seen by an ophthalmologist who has experience with the assessment and treatment of children, because some of these children may also have a treatable visual problem that accompanies or contributes to their primary reading or learning dysfunction.[110–113] Treatable ocular conditions can include strabismus, amblyopia, convergence and/or focusing deficiencies, and refractive errors. Missing these problems could cause long-term consequences from assigning these patients to incorrect treatment categories.

Pediatricians and primary care physicians play an extremely important function in acting as a medical home by helping parents decide whether further evaluations are needed and in coordinating care for the child after a diagnosis has been made.[98,108] A child should receive medical and psychological interventions as appropriate for diagnosed conditions.[108] If the pediatrician believes that the child has not received a proper assessment at school, then the pediatrician should refer the child for an outside independent educational evaluation by an educational psychologist, clinical psychologist with special training in learning assessments, neuropsychologist, developmental/behavioral pediatrician, neurodevelopmental pediatrician, or neurologist with appropriate expertise. Referral to an educational psychologist for psychoeducational assessment for the purpose of identifying special needs should be considered if the primary issue is the child's educational performance or learning problems. For patients with complex or long-standing educational problems that have been difficult to remediate, referral to a neuropsychologist, developmental/behavioral pediatrician, neurodevelopmental pediatrician, or neurologist with appropriate expertise should be considered for a more in-depth evaluation of brain function to asses overall cognitive, emotional, and behavioral functioning. A child should be referred to a neuropsychologist for problems such as learning, attention, behavior, socialization, or emotional control; a disease or developmental problem that affects the brain; or a brain injury from an accident or birth trauma. Pediatricians and primary care physicians should compile and provide a resource list of local specialists from whom the child can obtain proper help and from whom the family members can learn to become advocates for the child.[108] Pediatricians and primary care physicians should provide information and support to parents on learning disabilities and their treatment and should dispel the myths surrounding these disorders.[111] When parents inquire about a new technique or treatment concept, physicians should be ready to discuss the treatment and the current knowledge about its efficacy.[26] This discussion should include providing the parents with information regarding the lack of proven efficacy of vision therapy and other "alternative treatments."[111] Parents need to be informed that dyslexia is a complex disorder and that there are currently no quick cures. The American Academy of Pediatrics has information for families on what parents need to know about learning disabilities.[114]

Pediatricians and primary care physicians should be familiar with the IDEA, Section 504 of the Rehabilitation Act, and the ADA, because these acts define the rights of students with dyslexia and other specific learning disabilities.[95–97] The IDEA allows parents to request a formal educational evaluation by the school district to determine eligibility for special education.[96] Information for pediatricians on this legislation and its associated rights and procedures is available from the American Academy of Pediatrics.[98,108] Physicians can refer parents of children with learning disabilities to their state's parent training and information center. These parent-directed centers provide information and technical assistance to parents and professionals about family and student rights and responsibilities in special education.

Physicians who have a strong role in assisting school districts should recommend only evidence-based treatments and accommodations. They should also discourage school districts and parents from pursuing treatments that are not evidence based, because they are likely to waste time and resources.

THE EYES AND VISION

Visual Acuity and Refraction

Books for beginning readers usually have very large print of approximately 20/200 to 20/100 size. Good visual clarity and resolution are necessary to discern small print. There is no evidence that children with moderate myopia, moderate hyperopia, or moderate astigmatism have any greater difficulty in learning to read than do other children. Small amounts of hyperopia are normal in young children and are usually of no pathologic significance. The average refraction of white children in the United States is nearly 2.00 diopters (D) of hyperopia in the first 5 years of life and then gradually decreases into adolescence.[115] (A diopter is the unit of measurement of the refractive power of lenses equal to the reciprocal of the focal length measured in meters.) Nonmyopic significant refractive errors are present in 10% of children younger than 12 years. Children with uncorrected myopia will have reduced distance visual acuity and, thus, have difficulties with reading the board at school but no difficulty with near vision. Despite the condition, children with myopia have been found to be average to above-average students. Early optometric studies that have indicated increased hyperopia in children with reading difficulties are of limited significance, because the studies did not have control groups and were generally unreliable because they were performed without cycloplegia.[116] Before diagnosis and treatment, children with uncorrected high hyperopia may be uninterested in books and near tasks and secondarily experience difficulty starting to read, but they do not have an increased likelihood of true dyslexia.[115] There is no correlation between reading performance and any specific type of refractive error, including hyperopia or a need for glasses.[111]

Amblyopia causes reduced visual acuity and susceptibility to the crowding phenomenon, a difficulty with distinguishing letters in close proximity to one another, but only in the amblyopic eye/visual system. In children with amblyopia, fixation is usually performed with the fellow, nonamblyopic eye/visual system. In 1 study, microstrabismic amblyopia was associated with slower reading rates but not with dyslexia.[117] Nystagmus, bilateral cataracts, and retinal or optic nerve problems can interfere with visual acuity. Children with severe visual impairment are able to learn to read with assistance from spectacle correction for refractive errors and low-vision appliances. In general, ocular disease does not affect the ability of children to learn to read. Furthermore, children who are blind are able to learn to read using Braille. Vision impairment, in itself, has not been shown to be a predictor of reading disability.[58]

Saccades and Fixations

The eye movements used in reading are not similar to a typewriter typing. Smooth pursuit or tracking eye movements are not used in reading.[136] Reading uses saccades that are short-duration, high-velocity, small jumping eye movements. Reading uses both forward (rightward in English) saccades (85% of saccades) and backward or regression (leftward in English) saccades (15% of saccades).[118,119] Scanning a line of text in English involves a sequence of rightward and leftward saccades. The saccade length depends on the ability to recognize letters, the difficulty of the text, and the length of the word before the saccade. Experienced readers use longer saccades of approximately 2 degrees or 8 letters of average-sized print text.[120] Backward saccades are used for verification and comprehension, increase with the difficulty of the text, and are also used to jump to the next line. Early readers use more backward saccades. Visual perception is suppressed during saccades. Visual information is perceived during foveal fixations, which constitute 90% of our reading time.[111,118] Fixations may last 45 to 450 milliseconds and average 180 milliseconds. The duration of a fixation varies with the difficulty of the text being read.[118] When fixated, the eye rests on a content word and takes in a span of approximately 7 to 9 letters to the right of fixation and 3 to 4 letters to the left before it jumps over to the next fixation point. More letters are processed to the right of fixation if the eye is scanning from left to right, as in English, and the opposite would be true for reading a language than is scanned from right to left.

Early anecdotal publications in the optometric literature in the 1950s reported a possible oculomotor deficit that disrupted the normal saccadic reading pattern. In contrast, many studies subsequently have demonstrated that ocular coordination and motility are normal in children with dyslexia.[121–129] No difference was found between adults with dyslexia and controls on measures of saccadic accuracy and saccadic latency.[130] Readers with dyslexia have shown saccadic eye movements and fixations similar to those of the beginning reader and have shown normal saccadic eye movements when content is corrected for ability.[111,122] Improving reading has been shown to change saccadic patterns, but there is no evidence to suggest that saccadic training results in better reading. Readers with dyslexia have shown normal sequential saccadic tracking in tasks other than reading and oculomotor functioning.[125] Simulated saccadic "abnormalities" can be created by giving normal readers overly complex material or material in a new language.[122] Results of 3 studies by Rayner et al[131–133] were consistent with visual/linguistic-control models of eye-movement control and inconsistent with visual/oculomotor-control models. The saccadic patterns seen in readers with dyslexia appear not as a cause but as a result of their reading disability.## Decoding and comprehension difficulties, rather than a primary abnormality of the oculomotor control systems, are responsible for slow reading, increased duration of fixations, and increased backward saccades.[136] Children with dyslexia often lose their place while reading because they struggle to decode a letter or word combination and/or lack attention or comprehension, not because of a "tracking abnormality." Children with saccadic disorders, Duane syndrome, Moebius syndrome, and abnormal eye movements such as those with congenital motor nystagmus have shown the ability to learn to read fluently.[137] Dyslexia is no more frequent in these children with significant eye-movement disorders than in the general population.[137] Problems such as nystagmus interfere with foveal fixation time, yet affected children have not shown an increased likelihood of dyslexia. Thus, dyslexia is not the result of oculomotor deficits but, rather, the result of more central processing problems.[125]

Accommodation

Accommodation is the ability to focus accurately at near and is necessary for reading at near. Accommodative amplitudes are maximal in childhood and decrease naturally with age. The average amplitude of accommodation in children younger than 10 years is 14 D, which corresponds with a near point of accommodation of 2 to 3 in. Fifty percent, or 7 D, is available for sustained near activity; thus, young children can read comfortably at 6 in for a prolonged time. In the pediatric population, the incidence of accommodative insufficiency is low.[138,139] If it is present, symptoms can include discomfort or blurry or moving vision. Findings of accommodative insufficiency may include decreased visual acuity at near, a remote monocular near point, accommodative lag, and either esophoria or exophoria. Decreased accommodation has been associated with uncorrected high hyperopia, nonspecific viral illness, local ocular trauma, many medications, and functional problems.[138] There is no proof that

##Refs 14, 111, 112, 116, 118–128, and 134–136.

there is a difference in accommodative ability between normal and abnormal readers.[111] Difficulties in accommodation do not interfere with decoding but can interfere with the child's ability to concentrate on print for a prolonged period of time.[29]

The vergence system works to maintain fusion so that the eyes remain aligned on a visual target. Convergence is the inward turning of the eyes and is used for near reading. Various authors define convergence insufficiency differently. The diagnosis of convergence insufficiency is based on a remote near point of convergence or difficulty in sustaining convergence combined with asthenopic symptoms (sensations of visual or ocular discomfort) at near. The presence of 500 seconds of arc of stereopsis is required. These findings should be accompanied by a low convergence fusional amplitude, and/or a large exophoria or intermittent exotropia at near with a smaller exophoria, orthophoria, or esophoria at the distance. These latter findings alone do not constitute the diagnoses of convergence insufficiency, because they may be present with good convergence.[140,141] Of these findings, the most important are the ability to obtain and maintain convergence. The diagnosis of convergence insufficiency is relevant only if there are multiple findings accompanied by significant symptoms. Lack of sleep, illness, and anxiety are known to aggravate the problem. Older children, teenagers, and adults may become symptomatic because of large amounts of demanding near work and reading while fatigued. Patients typically present as teenagers or young adults with gradually increasing complaints of discomfort, eyestrain, headache, blurred vision, or diplopia during extended periods of studying.

The prevalence of convergence insufficiency has been reported to be in approximately 3% to 5% of the population. However, because of the differences in diagnostic criteria, some studies report the prevalence as being as low as 0.3% to 0.8%,[142,143] whereas a retrospective study of 8- to 12-year-olds in which findings alone were used classified 51% of the children with possible convergence insufficiency.[144] This classification system is obviously not valid, because it leads to classifying many normal children as abnormal. The disorder is much less common in children younger than 10 years. The incidence of ADHD was reported in 1 study to be increased in children with convergence insufficiency,[145] but additional analysis has revealed that the reported incidence was actually average when compared with large studies in which the prevalence of ADHD was evaluated.[17,18] Convergence amplitudes have not been correlated with reading comprehension.[146] A study of 735 children found no significant difference in school achievement for children who showed convergence insufficiency and those who did not.[147] Convergence insufficiency can interfere with a child's ability to concentrate on print for a prolonged period of time but does not interfere with decoding.[29]

Binocular Vision

True orthophoria—perfectly straight eyes—occurs rarely; most people demonstrate a small asymptomatic phoria, a latent deviation usually esophoria or exophoria, that should be considered a normal variant. A study of more than 3000 unselected students revealed a near phoria in most children. Several studies have investigated the connection between reading ability and the binocular and accommodative status of unselected children. No causal relationship was found between normal variants and reading/writing difficulties.[113] Manifest strabismus, known as tropias (eg, esotropia and exotropia), also has not been associated with dyslexia.[116,148]

Visual Processing

Processing of visual input is a higher cortical function.[14,15,111] Decoding and interpretation of retinal images occur in the brain after visual signals are transmitted from the eyes. Although vision is necessary for reading, it is the brain that must perform the complex function of interpreting the incoming visual images. Historically, many theories have implicated the visual system in the causation of dyslexia. The demise of these theories began in the 1980s with a series of related studies that systematically evaluated deficits in visual processes such as visualization, visual sequencing, and visual memory as basic causes of reading difficulties.[14,15] Visual theories of reading disability have become less and less popular, because only a few children who are poor readers actually suffer from perceptual malfunctions. Robinson and Schwartz[149] found no correlation between visual-perceptual abilities and reading ability. Larsen et al[150] found no differences in visual perception between normal and learning-disabled children. Larsen and Hammill[151] found no predictive relationship between standardized tests of visual perception and reading ability in their review of 60 studies. Morrison et al[152] found no perceptual deficits in children with reading disabilities. In short, visual skills do not reliably distinguish children who differ in reading ability.*** In their review in 2004, Vellutino et al[14] found no statistically significant differences in the studies between poor and normal readers on measures evaluating visual recognition and visual recall of letters and words. Visual deficits of the types from the early literature were found to be no more prevalent in poor readers than they

***Refs 2, 9–12, 14, 15, 116, 119–128, 134, 135, 137, and 149–151.

were in normal readers. In many studies that compared poor and normal readers, few significant differences were found on measures of visual processing ability when the influence of verbal coding was controlled.[14] Difficulties in maintaining proper directionality have been demonstrated to be a symptom, not a cause, of reading disorders.[14,15,111,122] Word reversals and skipping words and lines were attributable to linguistic deficiencies and not visual or perceptual disorders.[14,15,59]

In summary, vision problems can interfere with the process of reading; however, vision problems are not the cause of dyslexia. Significant refractive errors can make reading more difficult. Convergence insufficiency and poor accommodation, both of which are uncommon in children, can interfere with the physical act of reading but not with decoding and word recognition.[29] Thus, treatment of these disorders can make reading more comfortable and may allow reading for longer periods of time but does not directly improve decoding or comprehension.[29] If reading impairment is attributable solely to a visual problem, improvement in school performance should be observed once the problem is corrected.[153] Other than the need for long-term optical correction, these problems generally do not require extended treatment programs.

Many children with reading disabilities enjoy playing video games, including handheld games, for prolonged periods. Playing video games requires concentration, visual perception, visual processing, eye movements, and eye-hand coordination. Convergence and accommodation are also required for handheld games. Thus, if visual deficits were a major cause of reading disabilities, these children would reject this vision-intensive play activity.

ROLE OF THE OPHTHALMOLOGIST

Because routine pediatric vision screening is not designed to detect problems with near vision, children with suspected or diagnosed learning disabilities should undergo a comprehensive pediatric medical eye examination by an ophthalmologist who has experience with the assessment and treatment of children, because some children may also have a treatable visual problem along with their primary reading or learning dysfunction.[110–113,154] The medical history should include detection of any medical condition that could interfere with the child's ability to learn or a chronic medical illness that could cause school absences or difficulties concentrating or learning. The ocular history should include any eye or vision complaints that may make it difficult for the child to concentrate on reading for extended periods of time. It is important for the ophthalmologist to recognize that healthy children often have visual complaints from normal visual phenomena such as physiologic diplopia and relaxation of accommodation.[112,155] Also, most children (82%) who complain of eyestrain and headaches have a normal eye examination, whereas children with refractive error (78%), amblyopia (68%), or strabismus (58%) are free of eyestrain, which makes these complaints a poor marker of eye conditions in young children.[156]

The ophthalmologist should perform a complete dilated eye examination, including cycloplegic refraction. Cycloplegia with either 1% or 2% cyclopentolate is necessary for accurate refraction in young children. The strength should be based on the child's weight, iris coloration, and dilation history. In eyes with heavily pigmented irides, adjunctive agents such as tropicamide and/or phenylephrine hydrochloride may be necessary to achieve maximal cycloplegia and pupillary dilation. Vision testing with nonletter symbols may be necessary and may be especially important for testing children with dyslexia or other learning disabilities. The eye examination should place special importance on the detection of undiagnosed vision impairment by assessing visual acuity at the distance and near, significant refractive errors, amblyopia, or strabismus.

Strabismus, amblyopia, and refractive errors may require glasses, eye patching, eye drops, convergence training, prisms, or eye muscle surgery in accordance with standard principles of treatment.[110,157,158] In school-aged children without strabismus or amblyopia, correction of myopia should be considered approximately at -0.75 D or greater, astigmatism at 1.00 D to 1.50 D or greater, hyperopia at $+4.00$ D to $+4.50$ D or greater, anisometropic myopia at 2.00 D or greater, anisometropic hyperopia at 1.50 D or greater, and anisometropic astigmatism at 1.50 D to 2.00 D or greater.[110,159] Myopia and astigmatism are fully corrected, whereas high hyperopia is often undercorrected by up to 50% but no more than 3.00 D, depending on the clinical situation.[110] These guidelines should be adjusted on the basis of the patient's visual needs and symptoms, such as asthenopia and reduced visual acuity or lack of symptoms. Children with developmental delay or Down syndrome often hypoaccommodate and may benefit from spectacle correction at lower thresholds.[159]

A careful external ocular examination should be performed to determine if the child has problems such as dry eyes, blepharitis, or ocular allergies that could cause eye irritation that can secondarily interfere with his or her ability to concentrate and learn. Finally, a dilated retinal evaluation should be performed. Retinal or optic nerve problems can lead to strabismus, amblyopia, reduced visual acuity, and, rarely, photophobia.

Emphasis should be placed on the evaluation of ocular alignment, binocular function, stereopsis, accommodation, and convergence. Ocular alignment is assessed by using the corneal light reflection, the binocular red-reflex (Bruckner) test, cover/uncover, and alternate-cover tests in primary gaze with accommodative targets at distance and near when feasible; cover testing is most important. If an ocular misalignment is detected, multiple measurements of the ocular deviation using prisms in 1 or more fields of gaze at distance and/or at near is necessary. Ocular versions and ductions should be evaluated. Stereoacuity can be evaluated with the random dot E, Lang, or stereo fly test, whereas fusion can be tested with the Worth 4-dot test or Bagolini lenses. These tests can be performed at both near and distance when necessary.

Near visual acuity should be assessed in the evaluation of accommodation. The monocular near point of accommodation can be measured by conventional push-up technique using a ruler, Clark stick, or Costenbader accommodometer.[160] Before cycloplegia, dynamic retinoscopy can provide a rapid assessment of accommodative function and may be helpful in evaluating a child with high hyperopia, accommodative lag, or possible accommodative insufficiency. The accommodative facility can be assessed by alternately applying −2.00 and +2.00 lenses while the child reads monocularly. Symptomatic accommodative infacility may cause difficulty in shifting from far to near and near to far. The accommodative amplitude can be assessed by using increasing minus lenses while the child reads monocularly. Symptomatic accommodative insufficiency can cause blurry vision and discomfort, which can contribute to difficulties in concentrating on print for prolonged periods of time. Symptomatic accommodative insufficiency with a near point of accommodation well outside established norms can be treated with reading glasses or bifocals; it must be emphasized, however, that this condition is rare; hence, bifocals are rarely needed by children. Treatment of accommodation difficulties can make reading more comfortable but does not improve decoding or comprehension.[29]

The near point of convergence should be tested by using an accommodative target and measured with a ruler. Distance- and near-convergence amplitudes can be measured by using a base-out horizontal prism bar or rotary prism while the child is reading. Symptomatic convergence insufficiency can cause discomfort, eyestrain, blurry vision, diplopia, and headache, which can contribute to limited fluency by interfering with the child's ability to concentrate on print for a prolonged period of time. Symptomatic convergence insufficiency is a treatable condition. To improve reading comfort, it can be treated with near-point exercises, prism convergence exercises, or computer-based convergence exercises. Home computer-based convergence exercises are a newer method of treatment, and many children enjoy using the computer program. Over the years, orthoptic therapy has been adapted into simple visual tasks that can be taught in the office and conducted by the patient at home. Near-point convergence exercises generally consists of push-up exercises using an accommodative target of letters, numbers, or pictures; push-up exercises with additional base-out prisms; jump-to-near-convergence exercises; stereogram convergence exercises; recession from a target; and maintaining convergence for 30 to 40 seconds.[140,161,162] Generally, children are reevaluated in the office on a monthly basis.[140,161] Intensive in-office vision therapy is effective but not required.[161,163–165] Alternatively, for other patients, reading glasses with base-in prism or occlusion during reading can be used to treat the symptoms of diplopia but not the underlying convergence insufficiency.[140] The treatment of convergence insufficiency can help reading become more comfortable and may allow reading for longer periods of time, but this approach does not directly improve decoding or comprehension.[29]

In summary, the ophthalmologist should identify and treat any significant visual defect according to standard principles of treatment.[110,153,158,166] If no ocular or visual disorder is found, the child needs no further vision treatment. The ophthalmologist should not diagnose learning disabilities but should provide information on learning disabilities and reinforce the need for additional medical, psychological, educational, or other appropriate evaluation or services.[153,167] The ophthalmologist, when necessary, should compile and provide a resource list of local specialists to assist in obtaining proper help for the child.[167] In addition, the ophthalmologist should dispel myths surrounding these disorders and discuss the lack of proven efficacy of vision therapy and other alternative treatments with the parents. The American Academy of Ophthalmology and American Academy of Pediatrics have patient-education brochures for families on learning disabilities.[114,168]

SCIENTIFIC RESEARCH AND DISSEMINATION TO THE PUBLIC

Science advances by a process of modification. A continuous process of research and testing needs to take place to show that a treatment has demonstrable effect and benefits and to compare effectiveness between treatments. Over the last 50 years, progress in medicine has been based on controlled studies. Evidence-based medicine (EBM) categorizes different types of clinical evidence and ranks them according to the strength of their freedom from various biases. The "evidence pyramid" ranks testimonials, anecdotes, case reports, and case studies as poor sources of scientific information. Alternative medicine makes most of its claims by unsubstantiated testimonials.

EBM is the use of the most reliable current evidence to make treatment decisions. The practice of EBM integrates individual clinical expertise with the best available external clinical evidence from systematic research.[169] EBM is open to new evidence and revised conclusions. To use EBM, the physician should investigate the medical literature efficiently, read the methodology section to evaluate the quality of the evidence to determine the validity of the study, and, lastly, evaluate the results. The issue of validity speaks to the "truthfulness" of the information. Properly performed scientific studies offer the possibility of validity. Critical appraisal is a systematic process used to identify the strengths and weaknesses of a research article to assess the usefulness and validity of its findings. If the study is not valid, the data are not useful.[170] The physician must not take the conclusion seriously until the appropriateness of the study design, methodology, and statistical analysis have been critically evaluated. Thus, a physician cannot read the study abstract alone and be confident of the conclusion. Serious scientific, methodologic, and statistical flaws noted in some study reports that invalidated their conclusions are discussed in "Controversial Theories and Therapies."

Many types of statistical bias or other problems can be present in published scientific study reports. A positive ascertainment bias leads us to remember only positive results and positive studies. Positive studies are more likely to be published than are negative studies because of publication bias. Nonrandom sampling leads to difficulties generalizing the data. Selection bias includes self-selection, subject prescreening, and attrition. Manipulation of the data by rejection of "bad data" or "outliers" leads to biased data. Preliminary positive results in smaller studies often are not repeatable in larger randomized, placebo-controlled, double-blinded studies. A study with more preliminary supporting evidence is more plausible than one with weak or no previous supporting evidence. False-positive results are more likely in clinical trials that examine highly improbable hypotheses compared with hypotheses with a stronger basis in science.[171,172]

The Hawthorne effect may occur and bias the research when the experimental subjects change their behavior as a result of being observed, not in response to any particular experimental manipulation. The multiplicity problem may occur when the more often a hypothesis is tested, the more likely a positive result will be obtained. Similarly, when a lot of data are collected without a specific hypothesis in advance, some pattern will likely be found. An advanced hypothesis and appropriate statistical methodologies to control the probability of false-positive findings are essential for demonstrating credible scientific findings.

In poor research, the results or the conclusions may be skewed or biased to seem to be consistent with hypotheses proposed. Confirmation bias occurs when experiments are designed to seek confirmatory evidence instead of trying to disprove the hypothesis. Conclusions may be misleading or artificially inflated when data-derived, posthoc subgroup analysis is performed; new statistically significant outcomes are introduced for publication; nonsignificant primary outcomes are omitted from reports; or statistically significant secondary outcomes are upgraded to primary end points.[173]

Poorly conducted research may produce false-positive or false-negative results. Studies that do not control for the placebo effect may produce false-positive results. Studies with controls and "no-treatment groups" are necessary to evaluate the size of the placebo effect. The placebo effect may be a large portion of the positive responders.

The public is largely uninformed about the hallmarks of good research. The finding of an association is not a finding of cause and effect. There should be documented objectivity associated with research, and, when possible, there should be replication. Good research is rigorous and objective and requires peer review. Research findings should be tested and scrutinized from many angles by multiple, unrelated researchers. Ideally, a study of efficacy compares a treatment with a placebo or another treatment by using a double-masked controlled trial and well-defined protocol. Reports should describe enrollment procedures, eligibility criteria, clinical characteristics of the patients, methods for diagnosis, randomization method, definition of treatment, control conditions, and length of treatment. Standardized outcomes and appropriate statistical analyses should be used. Age-matched control groups are important in learning-disability studies.[112] Good baseline similarities of the population and the medical condition is necessary to compare like with like. All associated conditions or treatments should be controlled. The comparison groups must be the same except for the factor that is being studied. Large-scale studies provide more reliable conclusions by reducing the margin of error. The strongest evidence for therapeutic interventions is provided by carefully designed large-scale, randomized, double-blinded, placebo-controlled trials that involve good baseline similarities of patient population and medical condition with an adequate follow-up time and low study participant attrition rate.[170]

From a scientific perspective, "healthy skepticism" should be adopted by the research community[174] and the public. Scientists hesitate to accept research results unless they can demonstrate a statistical probability of more than 95% that the observations are not attributable to chance. The research community is willing to embrace a theory only when there is substantial convergent evidence from multiple sources. It often takes years to convince the research community that a theory has merit, but it frequently takes no time at all to convince the public.

The media now play a major role in providing information or misinformation on new scientific developments to the public. They may report claims by a tiny minority and place them on equal footing with the majority opinion or report claims before any research. Some scientists report their claims directly to the media, which circumvents the normal process of scientific review and debate. Public health messages are inadequate or distorted when journalists ignore complexities or fail to provide context.[175] The result is that a large share of the science seen by the public is flawed because of minimal or distorted scientific facts. This public information can influence the behavior of clinicians and patients. Media hype of the overstated findings of poorly designed research may change behavior and harm public welfare.[176]

In 1984, Levine[128] stated that pediatricians (and ophthalmologists) must serve as scientific consumer advocates and help parents, teachers, and the community at large to evaluate claims and insist on hard evidence regarding diagnostic and therapeutic modalities. Although it is prudent to be skeptical, especially with regard to prematurely disseminated therapies, it is important to also remain open-minded. Aggressive marketing, dramatic presentations, loosely reviewed journal articles, and fervent anecdotal reports of cure may convince school personnel and parents that visual training is the answer. Levine warned that in such cases, the pediatrician may be bypassed and considerable family and community resources may be diverted toward unsubstantiated interventions.

Helveston[177] stated that it has become traditional in medicine for new and unproven treatments to be evaluated under a protocol by qualified investigators on patients who give informed consent after the risks and benefits have been explained. The work is often performed at no charge, and results are reported for peer review. Only when the aforementioned criteria are met and it is shown that treatment is effective is treatment customarily offered on an unrestricted basis. According to Helveston, the use of tinted lenses or filters and vision therapy for learning disabilities does not follow these standards.

Silver[178,179] has written many articles on controversial therapies including vision therapy. He stated that a treatment approach can be considered suspect if the approach is proposed to the public before any research results are available or preliminary research has not been replicated; the proposed approach goes beyond what research data support; the approach is used in an isolated way when a multimodal assessment and treatment approach is needed; the treatment approach is being commercially promoted before the research shows any support for the proposed treatment; or there is clear research evidence showing that the approach does not work, yet the approach is still advertised commercially.

Kennedy et al[180] stated that unvalidated treatments often claim to be effective against a range of disorders with different symptoms and etiologies. Worrall[181] recommended that the public be suspicious of any therapy that claims to treat a large number of illnesses. He stated that the chronic nature of learning disabilities offers the ideal environment for fraud and quackery. He noted that parents often abandon common sense in their quest to help their struggling children and become easy prey for therapists who promise a cure.[181,182] Thus, the public must learn to carefully evaluate the information received in the face of aggressive promotion.

CONTROVERSIAL THEORIES AND THERAPIES

Magnocellular Deficit Theory

There is continuing interest in low-level impairments of the visual system as an etiologic factor in dyslexia. The visual system is composed of 2 parallel systems: the magnocellular (large-celled) (transient) system and the parvocellular (small-celled) (sustained) system.[183] The magnocellular system responds to high temporal frequency and object movement, and the parvocellular system is sensitive to low-frequency and fine spatial details.[183] The magnocellular component of the visual system is important for timing visual events and controlling eye movements when reading.[183,184] It is postulated that the magnocellular system suppresses the parvocellular system at the time of each saccade. This suppression terminates the activity in the parvocellular system to prevent activity elicited during a fixation from lingering into that from the next fixation. The magnocellular deficit theory of dyslexia proposes that without this suppression, the parvocellular activity from different fixations would be confused, which would result in a failure to keep separate neural activity elicited during different fixations. Specific reading disability in a small subset of patients with dyslexia has been attributed to a deficit in the magnocellular visual system.[183–187]

In 1983, Breitmeyer[183] proposed that reading disability is an expression of the disruptive effects of a temporal processing deficit in the magnocellular system. Stein and Walsh[184,187] suggested that this deficit in the inhibitory function of the magnocellular system produces a visual trace of abnormal longevity that creates masking effects along with visual acuity problems when reading connected text. This visual trace could be responsible for complaints of visual distortion and moving print in some people with dyslexia. Selective disruption of the magnocellular pathway via the posterior parietal cortex in certain people with dyslexia could lead to deficiencies in visual processing, visuospatial attention, and abnormal binocular control. Reading errors have been attributed to instabilities in binocular vision that result from destabilization of binocular eye position. However, eye-movement recordings have shown that poor readers and age-matched normal readers have comparable stabilities in binocular fixation. In another article, Stein and Walsh[187] concluded that people with dyslexia may be unable to process fast incoming sensory information adequately in the phonological, visual, and motor systems.

In 1991, Livingstone et al[186] found that disabled readers had abnormally long visual evoked-potential latencies in conditions of low contrast or with rapid changes of the stimulus. It was concluded that the temporal deficits were attributable to a defective magnocellular visual pathway, because this pathway preferentially responds at higher temporal rates and lower contrasts. This finding was not reproduced in a larger study by Victor et al,[188] who concluded that it was unlikely that a simple loss of magnocellular function readily manifest in the visual evoked potential is causally and specifically related to dyslexia. Also in opposition to Livingstone et al, May et al[189] found that the latency periods were shortened under low spatial frequency conditions. In 1993, Lehmkuhle et al[185] noted the lack of change in the latency of the visual evoked potential in reading-disabled children compared with the increased latency noted in children without a reading disability by using low spatial frequency target and high-frequency flicker fields. Their conclusion was that it is possible that a defect in the magnocellular pathway creates a timing disorder that precludes rapid and smooth integration of detailed visual information necessary for efficient reading. A letter to the editor from Victor[190] interpreted the findings of Lehmkuhle et al as showing that the equalization of the responses of normal readers and reading-disabled subjects with the addition of the flickering background reflects not only an increase in response latency in subjects with no reading disability but also a statistically insignificant shortening of response latency in reading-disabled subjects. Victor further stated that this finding defies a simple interpretation in terms of a loss of the magnocellular input.

Most of the evidence supporting the magnocellular theory comes from contrast-sensitivity and functional MRI studies on visual movement processing.[183–187] The studies supporting this theory are outnumbered by studies that have found no loss of contrast-sensitivity and other studies that have found contrast-sensitivity reductions or other findings inconsistent with a magnocellular deficit.[188–201] Thus, the evidence in support of the magnocellular theory is equivocal at best. Amitay et al[191] found that although some (6 of 30) subject with dyslexia showed impaired magnocellular function, they consistently showed impaired performance in auditory and nonmagnocellular visual tasks. Amitay et al hypothesized that the magnocellular pathway deficit is part of a more generalized deficit in fast temporal processing of visual, auditory, and perceptual information. Hutzler et al[129] suggested that pathologic abnormality in the magnocellular system may coexist with dyslexia but that it is not causal. Skoyles and Skottun[202] calculated that more people without dyslexia have magnocellular deficits than those with dyslexia, which challenges the view that dyslexia is the result of a magnocellular deficit. Many researchers have concluded that magnocellular system deficits and associated visual trace persistence are not significant causes of specific reading disability.[14,188–190,192–203]

Some study results involving tinted lenses, tinted filters, or occlusion seem to support the magnocellular theory,[183–187,204] and others refute it.[188–201,205] Iovino et al[204] evaluated 60 children with reading disability and comorbid conditions involving mathematics and ADHD in 1998. Reading accuracy, word-decoding rate, and reading comprehension were assessed by using red, blue, and no overlay. Colored overlays did not differentially affect the reading performance of subjects with and without reading disabilities. However, blue transparencies significantly improved reading comprehension in all groups but reduced the reading rate. The authors noted that these findings indicated that the magnocellular deficit theory may need to be reexamined. This result is important, because Breitmeyer, an author of the Iovino et al report, was also one of the authors who originally proposed the magnocellular deficit theory of dyslexia. Their alternative hypothesis involved the facilitation of attention. At the present time, there is insufficient evidence to base any treatment on this possible deficit.[203]

Colored Lenses and Overlays

At a national meeting in 1983, Irlen[206] proposed treatment with tinted lenses for a specific group of adults with reading problems, which she originally called the "scotopic sensitivity syndrome" (SSS) (now also called the Irlen syndrome or the Meares-Irlen syndrome). Before any supporting research, SSS was featured twice on the television program *60 Minutes*. On the program, it was stated that specially prescribed tinted lenses may be an effective method for the treatment of a variety of reading disorders, including dyslexia.[177] This national exposure led to great interest in the treatment. The initial claims of Irlen were based on observations, students' anecdotal accounts, and no formal experimentation. Supporters of the Irlen syndrome contend that the syndrome affects, to some degree, 12% to 15% of the general population and 45% of those with learning problems. People with this syndrome are thought to suffer from perceptual dysfunctions that cause visual distortion, light sensitivity, visual stress, and visual fragmentation from sensitivities to particular wavelengths of light not attributable to ocular conditions. This syndrome is postulated to interfere with overall attention, performance, fluency, and comprehension and create symptoms similar to learning disabilities. Proposed reading problems can include slow reading rate, poor comprehension, misreading words, skipping words and lines, reading in dim light, shortened reading times, and avoidance of reading. Writing problems can include slanted writing, unequal spacing, misaligning numbers, and errors while copying. General symptoms can include headaches, nausea, fatigue, burning eyes, and tearing. The *Irlen International Newsletter*[207] has reported that the Irlen syndrome should often be expected within the following clinical composites: bipolar spectrum disorder, sensory integration disorder, ADHD, anxiety disorders, school phobia, cranial cerebral trauma, visual dyslexia, tic disorders, reactive attachment disorders, migraines, mood disorder spectrum, recurrent automobile accidents, excessive daytime fatigue, and irritable bowel syndrome.

The Irlen method uses colored lenses and filters to reduce the offending wavelengths and correct these perceptual dysfunctions but does not treat children or adults with language deficiencies, dyslexia, specific learning disabilities, or attention deficit (Helen Irlen, MA., LMFT, personal communication, July 17, 2007). In addition to helping people read better, tinted lenses have been credited by multiple Irlen International newsletters with helping those who suffer from light sensitivity, discomfort, and distortions associated with a wide variety of different problems, including head injuries, concussions, whiplash, perceptual problems, neurologic impairment, memory loss, language deficits, headaches (including migraine), autoimmune disease, fibromyalgia, macular degeneration, cataracts, retinitis pigmentosa, complications from laser-assisted in situ keratomileusis (LASIK) and radial keratotomy, depression, seasonal depression, chronic anxiety, schizophrenia, multiple sclerosis, Asperger syndrome, and others.[207]

A multitude of different models have been used to explain the apparent "visual stress" and perceptual distortions that seem to occur in people with SSS. Currently, the magnocellular dysfunction theory and cortical excitability are being considered. Although the basis of SSS is unknown and the syndrome may not exist, interest in colored filters or overlays as a treatment for dyslexia persists and promotion continues.

Although Irlen and proponents of her method routinely refer to SSS as though it were an accepted medical syndrome, many experts question its validity.[177,208,209] It is interesting that the January 2006 *Irlen International Newsletter* stated that 1 reason that the problem of SSS escapes ophthalmologists is that ophthalmologists typically test under dim-light conditions.[207] In 1990, Helveston[177] stated that there is no evidence that SSS exists and also that there is no basis to use the word "scotopic," because the photopic system is used for reading. He also noted that reports of successful treatment of reading disorders using tinted lenses are based on anecdotal information and testimonials.[177] For many, the problem goes far beyond that of semantics. Hoyt[209] and others have maintained that SSS is not a recognized medical syndrome and consists merely of a group of vague and nonspecific symptoms derived from anecdotal accounts. To this day, there are no clearly established criteria for SSS. The only defining characteristic is a reported benefit of colored filters while reading.[208]

In 1990, the *Journal of Learning Disabilities* published 3 articles in a special series on use of the Irlen technique. A preface was written by Wiederholt,[210] the editor in chief, who noted that the Irlen techniques had received extensive media coverage without having data-based, experimentally controlled studies to validate either the syndrome or the treatment approach. He stated that the consulting editors who reviewed the studies for publication noted significant scientific and methodologic flaws that created a significant controversy as to whether the studies should be published in the journal. He further stated that on the basis of these 3 studies and the literature before 1990, the validity of the Irlen technique still had not been established.

These 3 studies were then reviewed in the journal by Parker,[176] Solan,[211] and Hoyt.[209] In their reviews of these 3 Irlen-filter studies, Parker, Solan, and Hoyt noted serious methodologic flaws. Parker concluded that the findings could not be considered statistically or scientifically valid. Because firm conclusions could not be drawn, Hoyt recommended a long-term (over 1-year) prospective multicenter trial with carefully constructed control groups of children with learning disabilities who have an ophthalmic or optometric examination at the study's onset and at least yearly thereafter.

The first article in the series was by Robinson and Conway,[212] who studied poor readers with symptoms of scotopic sensitivity. For the first 3 months, the study subjects used an "intermediate" set of lenses based on the student's first preference, then followed by use of "optimum" lenses for the next 9 months. Optimum color lenses were identified after a 2-hour diagnostic procedure that involved up to 130 colors. The use of the intermediate colors was expected to act as a "semiplacebo." The authors concluded that comprehension and accuracy but not reading rate improved using the optimum color lenses.[212] In his review of the study, Parker stated that the use of age scores was a major flaw, the improvement in all reading measures seemed developmental, and the treatment with the optimum lenses seemed to have no greater effect than the semiplacebo. He also noted that the study only had a 50/50 chance of obtaining a statistically significant finding because of the small study size (which was actually the best of the 3 studies).[176] Furthermore, no control group was used,[176,209] and 12 of the 44 subjects reported changes in remedial coaching, degree of assistance, or an alteration in the learning/supportive environment. Hoyt[209] and Solan[211] noted that the study authors stated that the participants had undergone optometric or ophthalmic examination within the year but did not provide the results. Because of the many weaknesses in this study, the conclusion is not valid.

The second study was by O'Connor et al[213] of 105 students from grades 2 to 6 who were reading below grade level. Students who displayed definite scotopic symptoms using the Irlen Differential Perceptual Schedule and displayed marked improvement in reading performance with a particular colored overlay were classified as scotopic. Students who did not show scotopic signs were classified as nonscotopic. Thirteen subjects were dropped from the study, because although they had scotopic complaints, they did not show any preference for color and showed no symptomatic or reading improvement with the colored overlays. Ninety-two children continued in the 1-week study.[213] The article's conclusion stated that reading rate, accuracy, and comprehension were significantly improved when the scotopic children read with the preferred colored overlay. In his review, Parker noted that the study was very short, and the subjects were divided into small groups, randomly and in an idiosyncratic manner.[176] The small group size diminished the study's statistical significance.[176] Reading measures varied between improvement, no change, and regression in 4 of 5 groups. The improvement in some of the subjects in the placebo-filter groups may have been attributable to the placebo effect.[209] The finding of regression may have been attributable to the unreliability or variability of the reading assessments. Solan noted that the improvement in reading was equivocal[211] and that the use of grade-equivalent scores was misleading.[176,211] Solan also noted that there was no optometric pretesting.[211] Most importantly, this study was highly flawed, because the children underwent biased selection.[209,211] Dropping the 13 subjects in the study led Parker to explain that using the same or similar measures to define the treatment group and to assess the effects of treatment is "criterion contamination."[176] On the basis of examination of the methodology of this study, the conclusion is not valid.

The third study, by Blaskey et al,[214] included 40 participants from the ages of 9 to 51 years who were self-referred for a study on Irlen treatment. Thirty-eight of these participants were found to have optometric problems. The study then included only subjects who tested positive for both SSS symptoms and vision problems. Thirty of the 38 originally chose to participate, but only 22 completed the study. The subjects were assigned to an Irlen-treatment, vision-therapy, or control group. The subjects underwent pretreatment and posttreatment optometric and reading tests. The Irlen-treatment group used Irlen lenses for 2 weeks and placebo lenses for 2 weeks, in random order. Three of 11 in the Irlen-treatment group preferred the placebo filter. Subjects in the Irlen-filter group noted a reduction in SSS symptoms, but no reading improvement or change in optometric testing results was noted. Three of 11 in the vision-therapy group dropped out. The remaining subjects in the vision-therapy group showed a reduction in SSS symptoms and improvement in optometric testing but improvement on only 1 of 4 reading subtests. Five of the 8 control subjects dropped out. The remaining control group was too small to be of any significance, but it was stated that they showed no change in vision status or symptoms or on any of the reading measures. Authors of past studies have remarked that the symptoms of SSS seem similar to convergence insufficiency.[209,211,213] This group with Irlen symptoms showed a high percentage of convergence and accommodative dysfunction, which challenges the claim that the symptoms of SSS are not attributable to vision abnormalities.[211,213] This finding highlighted the need for a formal definition of SSS. The main flaws in this study were that multiple treatments were given to the Irlen-treatment group and the unacceptably large loss of subjects. Parker[176] challenged the statistics in the study and stated that the probability of finding a statistically significant result when none existed was unacceptably high, which invalided the study.

Serious methodologic flaws have continued to be noted in subsequent SSS studies. In 1991, Evans and Drasdo[215] criticized the literature for having no sound theoretical basis for SSS and for the unscientific testing of precision tints. Robinson[216] reviewed the literature concerning tinted lenses and filters up to 1993. He reported that authors of some studies that used anecdotal comments and questionnaires reported improvements in symptoms of visual distortion. Although those survey studies have produced a high rate of positive anecdotal comments, they have not been supported by significant gains of reading achievement in controlled studies. The few noncontrolled studies that he reviewed showed evidence of inconsistent improvement in variable subskill areas of reading. One study showed initial positive gains in reading that were not sustained at retesting. Another study claimed that the positive effects may have been confounded with other remedial interventions given at the same time. In many studies with positive results, the effect of heightened expectations cannot be eliminated because of the lack of a control group. Robinson also noted that some studies with positive results were unable to be duplicated. Many studies found no significant improvement in reading when using colored filters. Robinson concluded in his review that improved print clarity may make the learning of word-attack skills more effective but will not teach such skills and must be accompanied by reading instruction when needed.[208,216]

Menacker et al[217] performed a cohort study (the results of which were published in 1993) using 6 different colored lenses, 1 neutral-density lens, and an empty spectacle frame and showed no reading-performance change or preferred tint among disabled readers.

In 1994, Wilkins et al[218] conducted the first double-masked placebo-controlled study to test the effect of colored filters on symptoms of SSS and reading performance.[218] Subjects who experienced headaches or eye strain in addition to reading difficulties were chosen. Both the precision-tint and placebo-control groups showed a reduction in symptoms of SSS, but a larger effect occurred in the group that used prescribed colored filters. Although the contribution of placebo effects was not entirely ruled out, this study's results suggested that some of the effects of colored lenses may not be entirely attributable to placebo. Although symptoms were reduced in this study, reading rate, accuracy, and comprehension were not affected by either the prescribed or placebo filters.

The study by Robinson and Foreman[219] in 1999 also highlighted the need for proper control procedures. This study measured the effect of Irlen filters on reading performance as well as students' perception of their academic ability. The study included a control group (no SSS and no filter) and 3 experimental groups (placebo, blue, and precision filters). All 4 groups showed increased accuracy and reading comprehension, and the 3 experimental groups, including the placebo group, demonstrated significantly more improvement than the controls. Subjects also perceived an improvement in their SSS symptoms regardless of whether they were wearing placebo tints, blue tints, or prescribed tints.[219] This study revealed a likely placebo effect not only on subjective symptoms but on actual reading performance.[208,219]

In 2002, Bouldoukian et al[220] reported on subjects who experienced SSS symptoms while reading and concluded that colored overlays improved reading speed. However, the results also revealed that greater than one-third of the subjects preferred the control filter and, overall, the subjects were not significantly more likely to prefer their colored overlay than the control filter.

Spafford et al[221] found that contrast reduction, but not lens color, permitted poor readers to be diagnostically differentiated from proficient readers. Lightstone et al[222] stated that the choice of color must be child-specific and requires trial and error. Multiple different methods have been used to select the lens or filter color.[218,223–225] Color selection has shown considerable variability[224] and poor test-retest consistency.[226] Also, the tint selected needed to be changed in up to 25% of subjects within 1 year in a study by

Stone.[227] In a study by Croyle, the blue background provided improvement in the reading rate in low-contrast conditions, whereas the blue background had a slight deteriorative effect under high-contrast conditions.[228] Solan et al[229] found that comprehension of poor readers was improved by using blue filters, whereas Christenson et al[230] found no significant difference in reading comprehension or reading rate when using blue filters. Iovino et al[205] found that blue transparencies significantly improved reading comprehension but reduced reading rate. In a study of yellow filters by Ray et al,[231] the conclusion stated that there was improvement in accommodation, convergence, and reading rates, but deeper analysis of the statistics revealed a question of significance.

Among the numerous criticisms of Irlen's treatment is the argument that precision tints are highly susceptible to placebo effects. By relying on anecdotal accounts or experiments that lack adequate placebo controls, interpretations of findings are speculative at best. Controlling for placebo effects requires, among other things, the inclusion of placebo filters of similar color to precision tints but outside the effective range of chromaticity. Such filters have been successfully produced but have rarely been implemented in Irlen-lens research. Many studies include control groups, but they are typically composed of children who use no filters during testing and who report no symptoms of SSS. Although this is a form of control, it does not adequately control for the possibility of placebo effects.[208] Results are inconclusive when placebo filters are not implemented.[208]

More recent published studies advocating the use of these therapies to treat reading difficulties have continued to have serious flaws in their methods, including biased sample selection, small sample size, biased interpretation, heightened expectations, combination with traditional remediation techniques, and insufficient control for the placebo effect to support the assertion.††† Some studies have claimed to detect some improvement in a few patients in 1 reading subskill but not in other areas. However, improvements in reading subskills do not necessarily translate into improvements in reading. Overall, study results have been inconsistent[208,216,223,232]; many studies have shown that colored overlays and filters are ineffective,[205,214,217,233–235] but a few studies have reported partial positive results.[212,213,218,222,224,231] Many unreported studies have shown no effect of colored filters on measures of either reading performance or SSS symptoms. Also, many of the studies cited as proof of Irlen-lens efficiency actually have been found to be inconclusive after deeper analysis. Not only are some findings less meaningful than they first appear, the large variability in the methodology, techniques, and largely negative results does not support the effectiveness of tinted lenses and tinted filters in these patients.‡‡‡

Contrary to the broad claims of many Irlen-treatment proponents that the syndrome is highly prevalent in the reading-disabled population, the efficacy, if any, of this approach seems to be limited to a small subgroup of children with reading problems. The positive evidence for the effects of colored overlays and filters on reading performance is limited. Worrall et al[182] noted that the studies indicated that fewer than 5% of readers who experience discomfort benefit from a change in contrast, brightness, or color on the page beyond what would be expected from a placebo treatment alone. Thus, colored filters and lenses may be ineffective, except that they act as a placebo. In 1999, Evans[237] explained that treating visual problems or perceptual symptoms will likely alleviate only the "visual component" of reading problems and will not impact the phonologic deficits underlying most cases of reading disabilities. Thus, even proponents of precision tints have maintained that although an improvement in print clarity may facilitate the process of learning to read, it is not enough to lead to spontaneous improvements in word-recognition skills and other complex elements of reading; therefore, remediation for underlying reading problems will still be required.[208] Rooney[238] advised the education community not to embrace SSS and its treatment for learning disabilities and dyslexia.

With nothing but a small amount of anecdotal evidence, CBS reported Irlen's claims to the public and circumvented the normal process of scientific review and debate. Despite the continued lack of definitive evidence of its effectiveness, colored lenses and filters continue to be promoted. Since 1990, the medical community has recommended that Irlen promoters design and perform rigorous prospective, masked, controlled scientific studies to document the effectiveness of their method. Scientifically, the burden of proof is on the developers and promoters of the Irlen method to provide strong evidence to show that their diagnosis is valid and their treatments are beneficial. Contrary to usual scientific practice, 1 Irlen center director stated that it is equally the responsibility of others to carry out this validation research.[177]

Behavioral Optometry

Skeffington was the director of education of the Optometric Extension Program from 1928 to 1976.[239] The Skeffin-

†††Refs 111, 166, 176, 208, 209, and 215.

‡‡‡Refs 14, 111, 112, 177, 178, 205, 208, 209, 211, 214, 215, 217, 223, and 233–236.

gton near-point stress model is the basis for much of behavioral optometry.[240] His theories were derived exclusively from his and his collaborators' (Harmon and Renshaw) clinical experience and never independently refereed or formally debated outside the Optometric Extension Program.[239] Skeffington's model states that binocular anomalies and refractive errors are not primary conditions but products of underlying near-point stress. The model states that near-work stress causes underaccommodation and overconvergence. Esophoria usually develops, but sometimes exophoria or myopia develops from the stress. The model further states that this esophoria is best treated preventively. Harmon's theories concern reading posture.

Skeffington recommends an examination using 21 procedures for every patient in a standard sequence.[241] The results of each test are then noted to be higher or lower than an "expected" value.[242] The "expected value" is an "ideal value," not a norm.[242] The Optometric Extension Program "expected value" for ocular alignment at near for children is 6 prism diopters of exophoria. Most people free from ocular symptoms have small amounts of latent strabismus (esophorias or exophorias) that should be considered physiologic. Ophthalmologic and optometric clinical studies have shown that the average near ocular alignment is approximately 1 prism diopter of exophoria.[243–246] Using diagnostic criteria that are not valid such as the developmental optometric "expected values" will lead to misdiagnosis of many conditions. Many children with typical latent strabismus have been labeled by developmental optometrists as abnormal and diagnosed with near-point stress and a "relative esophoria" if they show physiologic lower values of exophoria than their "expected value."

A recent model of vision, considerably different than the traditional optometric model, proposed by Scheiman[247] divides evaluation and treatment into 3 categories: (1) visual acuity, refraction, and eye health disorders; (2) visual efficiency skills of accommodation, binocularity, and ocular motility; and (3) visual information-processing skills of visual discrimination, visual closure, visual memory, visualization, visual-motor integration, and figure-ground perception.

The optometric literature has implicated accommodative spasm, accommodative insufficiency, ill-sustained accommodation, accommodative inertia, and binocular dysfunction as being linked with reading disorders.[111,113,116,247–250] The authors of most of these studies claim that patients experience visual symptoms that lead to degradation in reading performance.[249–252] Accommodative disorders are implicated in causing print blurring, daydreaming, decreased attention span, increased heart and respiratory rate, and poor posture.[253–256] Grisham et al[257] reported an increased incidence of various symptoms in slower readers but could not show a significant difference in reading ability between readers with normal and abnormal binocular function. There is no proof of cause and effect between decreased binocular function and symptoms or between symptoms and poor reading. Other studies have been unable to find an increase in the incidence of binocular disorders in children with reading difficulties or an association between motility disorders and reading ability.[124,126,127]

Training Glasses

"Training" or "developmental" lenses are low-plus power glasses to be used for reading to relieve stress. They are frequently used in conjunction with vision training. Behavioral optometrists believe that training lenses help the visual system develop and mature normally. Skeffington[240] stated that they are best prescribed preventively before a visual problem is identified. Hendrickson stated that every child would benefit from the use of "learning glasses" in the classroom.[258] It has been argued that treatment of accommodative dysfunctions with low-power reading lenses will eliminate secondary problems and their associated symptoms and thereby improve reading efficacy.[259,260] Although they do not provide best-distance visual acuity, they are used to teach the eyes to relearn distance-vision skills that have atrophied. They generally have a power of +0.50 to +1.00 D, and some incorporate bifocals or prisms. Practitioners have followed several highly variable methods to establish the dioptric value of the near correction.[261,262]

Greenspan[253] showed improvement in pencil-and-paper visual tasks and reading posture with the low-plus lenses. Keller and Amos[263] critically reviewed Greenspan's data and found the effect of the developmental lenses to be insignificant. Keller and Amos also noted that if there is an effect, it would imply some unique property of the +0.50 D lens regardless of the patients' refractive error. A study by Barry and Cochran[264] compared plano (no power) and +0.50 D lenses near prescriptions in young adults and found no significant difference in visual performance. Wildsoet and Foo[265] compared 13 children who wore plano lenses and low-power (+0.50 to +1.00 D) training lenses for 6 to 15 months and found no significant difference in reading comprehension. Beauchamp[266] discussed the issue of overprescription of spectacles in his review of vision training in 1986. The justification and benefit for routine integration of costly spectacles into the program is unsupported and often not discussed. Beauchamp stated that spectacles are provided to the vast majority of children undergoing optometric vision training despite the demonstrably low incidence of ocular motility or refractive deficits.[124,126,127,266,267] Blika[124] found that one third of children in his study had unnecessary glasses, and many had improper prescriptions.

Olitsky and Nelson[111] stated that there is no proof that there is a difference in accommodative ability between normal and abnormal readers and that there was no correlation between reading performance and any specific type of refractive error, including hyperopia or a need for glasses. Olitsky and Nelson noted that the very low power of the reading glasses or bifocals that are often prescribed throws further doubt on their usefulness in a child who often shows large amplitudes of accommodative ability.[111] In a critical review of the behavioral optometric literature before 2000 for the UK College of Optometrists, Jennings[239] declared that the literature revealed no convincing experimental evidence of any benefits from a low-plus prescription.

Vision Therapy

Vision therapy is an attempt to correct or improve ocular, visual processing, and visual-perceptual disorders. A task force representing the College of Optometrists in Vision Development, the American Optometric Association, and the American Academy of Optometry formulated the following policy statement: "Optometric intervention for people with learning related vision problems consists of lenses, prisms, and vision therapy. Vision therapy does not directly treat learning disabilities or dyslexia. Vision therapy is a treatment to improve visual efficiency and visual processing, thereby allowing the person to be more responsive to educational instruction."[268] A vision-therapy program consists of in-office and at-home exercises performed over weeks to months and may include training glasses.

Developmental optometrists divide vision therapy into 2 broad categories: classic orthoptic techniques and behavioral or perceptual vision therapy. Orthoptic techniques are used to correct accommodative and convergence dysfunctions as well as heterophorias and refractive errors that might be responsible for asthenopic symptoms (eye fatigue and discomfort often aggravated by close work). In behavioral vision therapy, eye-movement and eye-hand coordination training techniques are used to improve learning efficiency by improving visual processing skills. These visual processing skills include visual-spatial orientation skills, visual discrimination, visual closure, visual memory, and visual-motor integration. Behavioral vision therapists claim to improve the efficiency of eye movements to improve scanning and locating. Behavioral vision therapy is based on the premise that differences in children's visual-perceptual-motor abilities exist and that these perceptual-motor abilities influence cognitive and adaptive skills such as reading, writing, and motor activities used in activities of daily living. It has been recommended to improve visual skills and processing in the belief that they will improve learning disabilities, including speech and language disorders, and nonverbal learning disorders.[112]

Vision-Therapy Literature Review

Two major reviews of the vision-training literature were undertaken by Keogh, a professor of special education, in 1974 and again in 1985 with Pelland[267,269] to answer the questions of what optometric vision training is and for whom vision training is appropriate and effective. In 1974, Keogh[269] stated that the research on vision theory was sparse, fragmented, and, for the most part, methodologically flawed, and that the professional literature was characterized more by opinion than evidence. The 1974 review concluded with the observation that there was a lack of substantive and comprehensive evidence on which to make decisions about program effects and called for research to specify child and program characteristics that contribute to intervention outcomes.

Keogh stated that, in the 10 years after her first review, behavioral optometrists continued to offer and expand vision training to learning- and reading-disabled pupils, which led to her second review. She noted in her 1985 review that the necessary and sufficient components of vision training are unspecified and, thus, untested. Keogh and Pelland[267] stated that after detailed review of more than 35 program descriptions, there was not a single prototypic program model, which led to the comment that there were almost as many training programs as there were vision trainers. They noted that the variation in vision-training programs was so great that it was extraordinarily difficult to draw inferences about the effectiveness of the procedures. Furthermore, it seemed paradoxical that vision training was being recommended and used for a broad range of problems including preventive treatment.

Keogh and Pelland also noted that the nature of the relationship between vision, reading, and learning problems continues to be a troublesome theoretical question that has not been well answered by optometrists involved in vision training. Although much of the research basis for behavioral optometrists' interpretation was completed before 1975, in general, optometrists accept a link between poor reading and convergence inefficiencies, farsightedness, and near and distance phorias. Thus, many optometrists argue in favor of vision therapy for problems of convergence, accommodation, ocular motility, and binocular fusion. Keogh and Pelland reported that most of the reviewed studies did not meet rigorous research standards. In most of the reported studies the data were ambiguous with equivocal findings so that the importance of visual efficacy was undeterminable. They declared that to focus on a single aspect of learning problems and to interpret an association or relationship as if it has causal implications goes beyond the evidence.[267]

Keogh and Pelland stated that if visual processing problems are not the cause of many reading problems, vision training to improve visual efficiency is not the treatment of choice. They found little definitive evidence for the effectiveness of vision therapy even when the results were aggregated across studies and concluded that using this treatment would lead to wasteful and ineffective intervention efforts. They concluded that it is imperative that vision-training research receive systematic and rigorous testing and that the research be reported for review in a broader scientific arena.[267]

In 1984, Metzger and Werner[116] reviewed the ophthalmologic, optometric, and psychological literature on the use of visual training for reading disabilities. They found that refractive abnormalities, ocular motor abnormalities, and perceptual capabilities did not differ between reading-disabled children and those with no reading disability. In their review, they noted significant flaws in experimental methodology that supports the visually based hypotheses. They also found that visual-motor-perceptual training programs produced no further improvement in reading ability for affected children when compared with those in control groups.[116] Levine,[128] in his commentary on their article, remarked on the poor methodology in the reviewed studies, researchers having a vested interest, narrow interpretation of the findings, and an initial preconception that a factor in isolation causes reading disability. He recommended properly designing research on the use of vision training for learning disabilities.

In 1987, Beauchamp and Kosmorsky[122] extensively reviewed the interdisciplinary literature for the history of dyslexia and its relationship to neuropathology and eye movements. They concluded that eye movements are not the controlling factor in dyslexia or learning disabilities but are secondary to the comprehension difficulties. In addition, they concluded that approaches designed to improve visual perception by training are misdirected, because visual-perceptual problems do not underlie dyslexia. Their literature review revealed that visual-perceptual training seems to be ineffective and that controlled evidence for treatment efficacy has been found to be conceptually flawed, scant, and contradictory.

Complementary Therapy Assessment: Vision Therapy for Learning Disabilities was published in 2001 by the American Academy of Ophthalmology.[112] This report reviewed the literature on vision therapy for reading disabilities and concluded that there seems to be no consistent scientific evidence that supports behavioral vision therapy, orthoptic vision therapy, or colored overlays and lenses as effective treatments for learning disabilities. No well-performed randomized controlled trials (level I evidence) were found in the literature. The vision-therapy studies have shown an absence of a standard definition of the techniques that constitute vision therapy. Children included in the studies had been diagnosed with learning disabilities by using different criteria and may have been misdiagnosed or may have had additional conditions that confounded the findings. Furthermore, during a course of vision therapy, children were simultaneously receiving continued and even enhanced instruction in a standard or remedial educational setting and undergoing natural maturational changes. The results of subsequent studies have been inconsistent and have failed to reproduce many of these findings. The American Academy of Ophthalmology recommended that appropriately designed and methodologically rigorous scientific studies with a team approach using multidisciplinary educational specialists be conducted to assess the effectiveness of vision therapy.[112]

The Institute for Clinical Systems Improvement technology assessment report on vision therapy was published in 2003.[270] The Institute for Clinical Systems Improvement reports are designed to assist clinicians by providing a scientific assessment, thorough search, review, and analysis of medical literature of the safety and efficacy of medical technologies. The reports classify and grade references by their level of evidence. Two ophthalmologists and 2 optometrists were included on the panel on the topic of vision therapy. Their conclusions were that the studies of vision therapy are predominantly poor-quality case series that provided inadequate scientific evidence to enable a conclusion to be reached about the efficacy of vision therapy for patients with learning disabilities, amblyopia, strabismus, convergence insufficiency, or accommodative disorders. The committee encouraged masked, randomized, controlled trials of vision therapy for these potential uses. They recommended that these trials include clearly defined patient populations, control groups, clearly defined treatment programs, relevant outcome measures, and adequate patient follow-up to determine if any observed benefits are maintained.[270]

Rawstron et al[271] published a literature review of eye exercises in 2005. The review concluded that the results of small controlled trials and many case reports support the use of eye exercises in the treatment of convergence insufficiency but that there is no clear scientific evidence published in the literature to support the use of eye exercises in the remainder of the areas reviewed, including learning disabilities and dyslexia.

A 2005 Association for Research in Vision and Ophthalmology abstract by optometrists Sampson et al[272] discussed a randomized, masked, and controlled study of 96 suboptimally achieving children who showed visual information-processing delay and normal auditory/verbal language development. The experimental group underwent a visual training program designed to be typical of programs used in pediatric optometric practice. The control group received a placebo program that provided similar amounts of individual time with the children. Diagnostic educational testing took place before the study, at the conclusion, and 6 months after the completion of the programs. Both groups made significantly greater postintervention progress on most variables compared with that expected had no intervention occurred. Results for the entire group showed no significant between-group differences for all educational tests. Thus, results for the entire group did not provide evidence to support efficacy of the visual training program under investigation, which suggests that a placebo effect was responsible for much of the demonstrated improvement.

In 2005, the Convergence Insufficiency Treatment Group published data from a small, masked, placebo-controlled, multicenter, randomized clinical trial that showed that patients treated with office-based vision therapy improved more than those treated with minimally intensive home-based pencil push-up exercises or placebo.[165] The study used both findings and a symptom score. Eight of the 15 patients, or 53% of the patients treated with office-based vision therapy, were considered symptomatically "cured."[165] Kushner,[161] in his accompanying editorial, surveyed 20 pediatric ophthalmologists and 15 orthoptists who treat convergence insufficiency. His survey revealed that most pediatric ophthalmologists and orthoptists do not use unmonitored home treatment with pencil push-ups. Generally, orthoptic therapy prescribed by pediatric ophthalmologists and orthoptists consists of push-up exercises using an accommodative target of letters, numbers, or pictures; push-up exercises with additional base-out prisms; jump-to-near-convergence exercises; stereogram convergence exercises; and recession from a target. The exercises are performed at home, and the children are reevaluated in the office on a monthly basis. Kushner retrospectively reviewed his last 20 patients with convergence insufficiency treated with these orthoptic techniques. Sixteen of his 20 patients (80%) reported complete resolution of symptoms and were objectively "cured" using the same criteria as in the study.[160] The Convergence Insufficiency Treatment Group study showed that convergence insufficiency can be improved with in-office vision therapy, but the accompanying editorial revealed that properly prescribed and monitored home treatment is also very effective.[161,165]

The Convergence Insufficiency Treatment Group[163] published a larger second study in 2008, which was a randomized clinical trial comparing home-based pencil push-up exercises, home computer vergence therapy, office-based orthoptic vision therapy with home reinforcement, and office-based placebo therapy with home reinforcement in 221 children in a 12-week study. Symptomatic improvement was noted in 43% of the home-based pencil push-up exercises group, 33% of the home computer vergence therapy group, 75% of the office-based vision therapy with home reinforcement group, and 35% of the office-based placebo therapy with home reinforcement group. The Convergence Insufficiency Treatment Group study showed better improvement with intensive office-based vergence/accommodative and home reinforcement therapy compared with less intensive home treatments or placebo. Wallace,[164] in his accompanying editorial, noted that neither home-based treatment group used in this study was an ideal comparison group, because fewer actual hours of treatment were received, and the home therapy was less intensive. Granet,[273] a site principle investigator for the study, wrote a letter to the editor concerning the methodology of the study. He stated that the difference between treatment groups could have easily been affected if the time in true treatment had been equalized.

Another major criticism of the 2 studies is the definition of convergence insufficiency. The criteria for study inclusion was a near exophoria at least 4 prism diopters greater than at far, a receded near point of convergence, insufficient positive fusional vergence at near or minimum positive fusional vergence, and a minimum symptom score. Using these diagnostic criteria may overestimate convergence insufficiency. Although the convergence-insufficiency symptom survey has undergone validation,[274] many of the symptoms in their symptom-scoring system are too vague and repetitive. Two examples are: (1) Do your eyes hurt when reading or doing close work? and (2) Do your eyes ever feel sore when reading or doing close work? Also, many of the symptoms used in the symptom score are nonspecific. Two examples are: (1) Do you read slowly? and (2) Do you have trouble remembering what you have read? Using this symptom survey, many people without convergence insufficiency may have a symptom score that qualifies them for the study. Finally, the use of symptoms in children may be unreliable. In a separate study, complaints such as eyestrain and headaches have been found to be poor markers of eye conditions in young children.[156]

The apparent superiority of office-based orthoptic vision therapy over home-based exercises in these 2 studies is not as strong as it first seemed. This problem was noted in the editorials[161,164] that accompanied both the 2005 and 2008 convergence-insufficiency treatment studies and also in a letter to the editor by Granet.[273] The major weakness of these studies was that the study groups were not appropriately chosen to provide a proper comparison. Treatment with minimally intensive pencil push-ups is not representative of the standard of care and, thus, does not provide the appropriate comparison. The comparison group should consist of the home exercise methods that are frequently prescribed by pediatric ophthalmologists or orthoptists and should be for the same number of hours and intensity as the in-office vision therapy. Sethi,[275] in his letter to the editor, noted that sustained convergence should have been stressed in performing the home pencil push-up exercises. Methodologically, the 2008 study is weakened, because it included 2 different variables and compared different treatments and 2 different intensities of treatment.

Jennings[239] reviewed behavioral vision->therapy studies for the UK College of Optometrists. His report on the evaluation of the theory and practice of behavioral optometry was published in 2000. In his review he noted that many studies showed methodologic and statistical weaknesses. He commented that careful study design is essential, because with training and practice, perceptual judgments improve. This improvement would be greatest if the patient is encouraged and reinforced. He also questioned whether improvement on the training task would transfer to routine activities. He concluded that the merits of vision therapy are extremely difficult to assess and that there is a lack of controlled studies to support behavioral management strategies. Jennings' conclusion was that behavioral optometric therapies do not satisfy evidence-based scrutiny.

On behalf of the UK College of Optometrists, Barrett[276] in 2009 reviewed studies of vision therapy published since the Jennings report in 2000. Barrett remarked that the theory and practice of behavioral optometry remain controversial, especially when considered from the perspective of the traditional optometrist. This is because many of the patients that behavioral optometrists are treating would not exhibit any abnormality under clinical assessment using traditional optometric approaches. Barrett reviewed evidence in 10 categories: accommodative/vergence disorders; underachieving child; prisms for near binocular disorders and for producing postural change; near-point stress and low-plus prescriptions; low-plus lenses at near-to-slow myopia progression; therapy to reduce myopia; therapy of amblyopia and strabismus; training central and peripheral awareness and syntonics; sports vision therapy; and neurologic disorders and neurorehabilitation after trauma/stroke. Barrett found that vision therapy for convergence insufficiency seemed to have some benefits but that further large-scale controlled trials that used proper controls were needed. He reported that vision therapy cannot currently be considered as an evidence-based treatment for reading or learning disorders. He declared that the large majority of behavioral management techniques were to be considered unproven until more rigorous trials were undertaken. His report concluded that the continued absence of rigorous scientific evidence from well-designed trials to support behavioral management approaches, and the paucity of controlled trials in particular, represented a major challenge to the credibility of the theory and practice of behavioral optometry. Barrett's final conclusion was that these approaches were not evidence-based and could not be advocated.[276]

A 2009 article in *Optician Online* commented on Barrett's study. The clinical editor of *Optician Online* stated that although some practitioners may be convinced from their own experience of the effectiveness of behavioral optometry, the lack of sound evidence-based research supporting this stance will always leave it open to the criticism that all it does is pay attention to a perceived problem and thereby influence its expression. The editor contended that it seemed less than ethical to charge for such interventions under a cloak of clinical practice until good evidence for the techniques exists.[277]

Summary on Vision Therapy

Some optometrists attribute reading disabilities or a portion of them to 1 or more subtle ocular or visual abnormalities. The basic tenet of their hypothesis is that children with reading disorders have an increased incidence of vision abnormalities. The College of Optometrists in Vision Development estimates that more than 60% of problem learners have undiagnosed vision problems that contribute to their difficulties. This claim has not been scientifically established. Many children without vision problems have been labeled as abnormal, because typical physiologic latent strabismus is not taken into account. Optometrists also claim that visual dysfunction in children impairs their ability to respond to the specific instruction intended to remedy the disability. However, the association of binocular and other vision anomalies with learning disabilities, as well as the significance of any association, has not been scientifically demonstrated. Thus, the nature of the relationship between vision problems and reading and learning problems continues to be a troublesome theoretical question that has not been answered adequately by optometrists involved in vision training.[267] Currently, there is inadequate scientific evidence to support the view that subtle eye or visual problems, including abnormal focusing, jerky eye movements, misaligned or crossed eyes, visual-motor dysfunction, binocular dysfunction, perceptual dysfunctions, or hypothetical difficulties with laterality or "trouble crossing the midline" of the visual field, cause or increase the severity of learning disabilities.§§§ Statistically, children with dyslexia or related learning disabilities have the same visual function and ocular health as children without such conditions.|||||| Visual problems may coexist with dyslexia but seem to be present with the same incidence as in the population in general; furthermore, no consistent relationship between visual function and academic performance and reading ability has been shown.¶¶¶ Although it is important to have adequate eyesight and ocular motility to read with the greatest efficiency, subtle or severe eye defects do not cause decoding or comprehension difficulties.

Because visual problems do not underlie dyslexia, approaches designed to improve visual function by training are misdirected.[122,128,137,153,266,267] Optometric vision training is based on the premise that reading is primarily a visual task. Many authors in the optometric literature proclaim the usefulness of vision therapy for reading and learning disabilities. Proponents of vision therapy claim that treatment of these visual abnormalities will help children with learning disabilities be more responsive to educational instruction, but this hypothesis has not been proven scientifically. Also, many of the abnormalities that are said to cause problems with reading are undefined and unspecified, which makes evaluation of the claims of successful treatment difficult to analyze. It is even more difficult to determine any possible benefit of vision therapy when used "preventively."

Over the last 35 years, many reviews of the literature that optometry uses to support vision therapy have been performed. Reviews of the vision-therapy literature revealing a lack of scientific support have been performed by researchers in reading and education, pediatricians, and ophthalmologists. Many of the detailed reviews that scientifically questioned the credibility of the theory and practice of vision therapy have been performed recently by optometrists.[181,182,239,270,276] Detailed review of the vision-therapy literature has revealed significant weaknesses, because most of the information has been of poor statistical and scientific quality. Many claims supporting vision therapy are old or found in newsletters, flyers, books without research, or nonedited or loosely reviewed publications. Many of the references used to support the claims in these articles do not relate directly to the topic. Often, a variety of criteria have been used in diagnosing subjects included in the study, and a variety of treatment programs have been used within a study. In addition, the investigator often has a vested interest in the outcome of the study. Many of the studies that support vision therapy use small numbers, and they typically rely on case studies, self-reports, anecdotal information, and testimonials. Studies have been poorly designed, failed to "mask" the investigator, and used inadequate or poor controls so that bias and placebo effects may have confounded the results.### In general, these research methods and references show poor scientific validation.[62,112,270,271]

Scientific evidence does not support the claims that visual training, muscle exercises, ocular pursuit-and-tracking exercises, behavioral/perceptual vision therapy, training glasses, prisms, and colored lenses and filters are effective direct or indirect treatments for learning disabilities.**** There is no valid evidence that children who participate in vision therapy are more responsive to educational instruction than children who do not participate.†††† The reported benefits of vision therapy, including nonspecific gains in reading ability, can often be explained by the placebo effect, increased time and attention given to students who are poor readers, maturation changes, or the traditional educational remedial techniques with which they are usually combined.‡‡‡‡

§§§Refs 14, 26, 111–113, 116, 119–128, 134–138, 154, and 266.

||||||Refs 2, 9–12, 14, 15, 111–113, 116, 119–128, 134–137, 149–151, 153, 166, 178, 239, 266, 267, 270, and 276.

¶¶¶Refs 118–121, 123, 124, 126, 127, 134, 135, and 149–151.

###Refs 111–113, 116, 122, 128, 136, 153, 166, 178, 239, 266, 267, 270, 271, and 276.

****Refs 14, 24–26, 29, 31, 34, 39, 44, 82, 111–113, 116, 122, 128, 136, 152, 153, 166, 178, 205, 208, 214, 233–235, 239, 266, 267, 270–272, and 276.

††††Refs 14, 24, 29, 34, 111–113, 116, 122, 128, 136, 152, 153, 166, 178, 239, 266, 267, 270–272, 276, and 278.

‡‡‡‡Refs 111–113, 116, 136, 239, 266, 267, 270, and 278.

Other than convergence-insufficiency treatment, the optometric claims that vision therapy improves visual efficiency cannot be substantiated. Treatment of convergence insufficiency helps the reader maintain visual effort for prolonged reading, but treatment of convergence insufficiency by any method is not a treatment for dyslexia. These ineffective, controversial methods of treatment may give parents and teachers a false sense of security that a child's reading difficulties are being addressed, may waste family and/or school time and resources, and may delay proper instruction or remediation.

Because they are difficult for the public to understand and for educators to treat, learning disabilities have spawned a wide variety of scientifically unsupported vision-based diagnostic and treatment procedures.§§§§ Despite the continued lack of definitive evidence of its effectiveness, vision training for improving visual efficiency and visual processing has been widely used, at great cost, over the last half-century in many thousands of children with learning disabilities and also as a "preventive treatment." During these years, the medical and educational communities have recommended designing and performing rigorous prospective, masked, controlled scientific studies to document the effectiveness of vision therapy. The burden of proof is on the promoters of vision therapy to provide strong evidence to show that their testing methods are valid, that an association exists between visual dysfunction and learning disabilities, and that their treatments are beneficial. Outcome studies documenting effective results using EBM are necessary before vision therapy can be recommended. Continuing critical literature review will ensure that the best evidence is disseminated and poor-quality studies are subject to proper scrutiny.

§§§§Refs 12, 14, 24, 111–113, 116, 122, 128, 136, 152, 166, 177, 178, 205, 208, 209, 211, 214, 215, 217, 223, 233–236, 239, 266, 267, 270–272, 276, and 278.

MANAGEMENT SUMMARY

Parents should read aloud to their children to help develop language skills. If early warning signs of learning difficulties are detected in preschool-aged children by parents or teachers or during developmental surveillance or screening, the primary care provider should refer the child for early evaluation and intervention. Cost-effective prevention, early identification, and early phonologic awareness intervention programs in kindergarten through 2nd grade should be encouraged. Early identification of children who show delays or difficulties should be a high priority for elementary school teachers. Evaluation for learning disabilities should be considered for all children who present with school difficulties, even if reading difficulty is not the chief complaint.[34] A child with suspected learning disabilities should be placed into remediation and be referred as early as possible for educational evaluation.

A multidisciplinary team consisting of educators, educational remediation specialists, special service professionals, psychologists, and pediatric specialists in neurodevelopmental disabilities or developmental and behavioral pediatrics should be called on to diagnose and treat suspected learning disabilities in children. Making the correct diagnosis of the specific type of learning disability along with any comorbid conditions is of paramount importance before any therapeutic regimen can be prescribed.[167] To outline the educational goals and services that the student needs to be successful, an IEP contract should be developed. The IEP should describe what services will be needed, including specific remedial interventions and accommodations, and which type of program would be best and should set guidelines for measuring future educational progress.

The remedial program should be individualized. Remedial programs should include specific instruction in decoding, fluency training, vocabulary, and comprehension.¶¶¶¶ Most programs include daily intensive individualized instruction to explicitly teach phonemic awareness and the application of phonics.#### Later, syllable instruction, morphology, memorization of sight words, spelling, syntax, and semantics are taught.[55] Comprehension is gained through fluency training, vocabulary instruction, and active reading comprehension.[34,35] Practice-reading aloud at home is essential. Because people with dyslexia have a persistent problem and continue to read slowly throughout their life, it often becomes necessary to adapt the learning environment.[24,25,34,81] Schools can implement academic accommodations and modifications to help students with dyslexia succeed.

Children with learning disabilities and possible visual problems suspected by their parents, teachers, or physician should be seen by an ophthalmologist who has experience with the assessment and treatment of children, because some of these children may also have a treatable visual problem along with their primary reading or learning dysfunction.[110–113,154] Treatable ocular conditions include strabismus, amblyopia, convergence and/or focusing deficiencies, and refractive errors. The ophthalmologist should identify and treat any significant visual defect according to standard principles of treatment.[110,113,153,166] The primary care pediatrician and ophthalmologist should not diagnose learning disabilities but should provide information on learning disabili-

¶¶¶¶Refs 1, 14, 32–35, 43, 55, 60, 63–65, and 81.
####Refs 1, 14, 24, 25, 30–35, 55, 60, and 63–65.

ties and reinforce the need for additional medical, psychological, educational, or other appropriate evaluation or services.[167] In addition, the primary care pediatrician and ophthalmologist should discuss the lack of proven efficacy of vision therapy and other alternative treatments with the parents. Finally, the public must learn to carefully evaluate the information that they receive in the face of aggressive promotion.

CONCLUSIONS

Underachievement is not synonymous with specific learning disability.[279] Learning disabilities arise from neurologic differences in brain structure and function that affect the brain's ability to store, process, or communicate information. The consensus of educators, psychologists, and medical specialists is that children who exhibit signs of learning disabilities should be referred as early as possible for educational, psychological, neuropsychological, and/or medical diagnostic assessments, because the beneficial effects of early identification and intervention are apparent in many studies. Children diagnosed with learning disabilities should receive appropriate support and individualized evidence-based educational interventions combined with psychological, medical, and visual treatments as needed.

Reading difficulties constitute a diverse group of problems that include dyslexia and secondary forms of reading difficulties caused by visual or hearing disorders, intellectual disability, experiential and/or instructional deficits, and other problems.[14,24–26] Missing these problems could cause long-term consequences from assigning these patients to incorrect treatment categories. Dyslexia is a primary receptive language-based reading disorder secondary to a neurobiological deficit in the processing of the sound structure of language called a phonemic deficit that makes it difficult to use the alphabetic code. Because of our rudimentary knowledge of learning disabilities, including dyslexia, there currently are no simple remedies. Because dyslexia is a language-based disorder, treatment should be directed at this etiology.***** The prognosis depends on the severity of the disability, the specific patterns of strengths and weaknesses, and the appropriateness, amount, intensity, and timing of the intervention. Early recognition and individualized, interdisciplinary management strategies are the keys to helping children with dyslexia. Early intervention with intense, explicit instruction is critical for helping students ameliorate the lifelong consequences of poor reading.

Visual problems do not cause dyslexia. Scientific evidence does not support the efficacy of eye exercises, behavioral/perceptual vision therapy, training glasses, or special tinted filters or lenses in improving the long-term educational performance in these complex pediatric neurocognitive conditions. Recommendations for multidisciplinary evaluation and management must be based on evidence of proven effectiveness demonstrated by objective scientific methodology.[106,112,239,270,276] It is important that any therapy for learning disabilities be scientifically established to be valid before it can be recommended for treatment.[106] Because vision therapy is not evidence based, it cannot be advocated.

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OTHER RESOURCES

International Dyslexia Association: www.interdys.org

National Center for Learning Disabilities: www.ncld.org

Learning Disabilities Online: www.ldonline.org

Interdisciplinary Council on Developmental and Learning Disorders: www.icdl.com

Great Schools Inc/Schwab Learning: www.schwablearning.org

All Kinds of Minds: www.allkindsofminds.org

Children and Adults With Attention Deficit/Hyperactivity Disorder: www.chadd.org

National Center for the Study of Adult Learning and Literacy: www.ncsall.net

PACER Center: www.pacer.org

Parental Information and Resource Centers: www.ed.gov/programs/pirc/index.html

Family Voices: www.familyvoices.org

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Learning Disabilities, Dyslexia, and Vision

Sheryl M. Handler, Walter M. Fierson and the Section on Ophthalmology and Council on Children with Disabilities, American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, and American Association of Certified Orthoptists

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