19. Fountas IC, Pinnell GS. Guided Reading: Good First Teaching for All Children. Portsmouth, NH: Heinemann; 1996:177-8.
20. US Department of Education. Reading Milestones. Available at: https://www2.ed.gov/parents/academic/help/reader/part9.html. Accessed May 22, 2017.
21. Liu Y, Liu H, Hau KT. Reading ability development from kindergarten to junior secondary: latent transition analyses with growth mixture modeling. Front Psychol 2016;7:1659. eCollection 2016.
22. Bhattacharya A. Children and adolescents from poverty and reading development: a research review. Read Writ Q 2010;26:115-39.
23. Conradi K, Amendum SJ, Liebfreund MD. Explaining variance in comprehension for students in a high-poverty setting. Read Writ Q 2016;32:427-53.
24. Kovachy VN, Adams JN, Tamaresis JS, Feldman HM. Reading abilities in school-aged preterm children: a review and meta-analysis. Dev Med Child Neurol 2015;57:410-19.
25. Woodcock RW, Mather N, Schrank FA. Woodcock-Johnson III Diagnostic Reading Battery. Itasca, IL: Riverside Publishing; 2004.
26. Good RH, Kaminski RA. DIBELS Next Assessment Manual. Eugene, OR: Dynamic Measurement Group; 2011.
27. Wagner RK, Torgesen JK, Rashotte CA, Pearson NA. Comprehensive Test of Phonological Processing - Second Edition (CTOPP-2). Austin, TX: Pro-Ed; 2013.
28. Woodcock RW. Manual for the Woodcock Reading Mastery Tests. 3rd ed. San Antonio, TX: Pearson; 2011.
29. Fountas I, Pinnell GS. Benchmark Assessment System. Portsmouth, NH: Heinemann; 2007.
30. Beaver JM, Carter MA. The Developmental Reading Assessment. 2nd ed. (DRA2). Upper Saddle River (NJ): Pearson; 2006.
31. Dunn LM, Dunn DM. Peabody Picture Vocabulary Test. Minneapolis, MN: Pearson; 2007.
32. Pearson NCS. Inc. AIMSweb Reading. New York, NY: Pearson; 2012.
33. Curriculum Associates, LLC. i-Ready K-12 Diagnostic. North Billerica, MA: Curriculum Associates, LLC; 2011.
34. Northwest Evaluation Association. Technical manual for measures of academic progress and measures of academic progress for primary grades. Lake Oswego, OR: Northwest Evaluation Association; 2009.
35. Clay MM. An Observation Survey of Early Literacy Achievement. 2nd ed. Portsmouth, NH: Heinemann; 2002.
36. Wood F. PAR: Predictive Assessment of Reading: Pre-K to Grade. 3rd ed. Technical Manual. Clemmons (NC): Red-e Set Grow, LLC; 2013.
37. Williams KT. Group Reading Assessment and Diagnostic Evaluation. Circle Pines, MN: American Guidance Service; 2001.
38. Scholastic, Inc. SRI College & Career: Technical Guide. New York: Scholastic; 2014.
39. Partnership for Assessment of Readiness for College and Careers. Available at: http://parcconline.org/about/the-parcc-tests. Accessed June 6, 2017.
40. MacGinitie WH, MacGinitie RK, Maria K, Dreyer LG, Hughes KE. Gates-MacGinitie Reading Tests. 4th ed. Itasca, IL: Riverside; 2000.
41. Wiederhollt JL, Bryant BR. GORT4: Gray Oral Reading Tests. Austin, TX: Pro-Ed; 2001.
42. Invernizzi M, Juel C, Swank L, Meier C. Phonological Awareness Literacy Screening for Kindergarten (PALS-K). Charlottesville, VA: University Printing; 2003.
43. Invernizzi M, Meier C, Juel C. Phonological Awareness Literacy Screening for grades one through three. Charlottesville, VA: University Printing; 2003.
44. Roswell FG, Chall JS, Curtis ME, Kearns G. Diagnostic Assessments of Reading: Second Edition technical manual. Chicago, IL: Riverside Publishing Company; 2005.
45. The Psychological Corporation. Early Reading Diagnostic Assessment. 2nd ed. San Antonio, TX: Harcourt; 2003.
46. Leslie L, Caldwell JS. Qualitative Reading Inventory. 5th ed. Boston: Pearson; 2011.
47. Torgesen JK, Wagner RK, Rashotte CA. Test of Word Reading Efficiency – Second Edition (TOWRE-2). Austin, TX: Pro-Ed; 2012.
48. Yopp HK. A Test for Assessing Phonemic Awareness in Young Children. Read Teach 1995;49:20-29.
49. Smarter Balanced Assessment Consortium. Available at: https://www.smarterbalanced.org/assessments/. Accessed June 6, 2017.
50. Kulp MT, Ciner E, Maguire M, et al., VIP-HIP Study Group. Uncorrected hyperopia and preschool early literacy: results of the Vision in Preschoolers–Hyperopia in Preschoolers (VIP-HIP) Study. Ophthalmology 2016;123:681-9.

Reading difficulties and the pediatric ophthalmologist

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Reading

Reading is the complex process of extracting meaning from written symbolic characters. Learning to read in English is particularly challenging because of the large number of irregular words, and most of kindergarten through 3rd grade is dedicated to learning this difficult task. Reading requires adequate vision and memory, ability to sound out and recognize words, vocabulary, knowledge of word and language structures, ability to name objects rapidly, and capacity to sustain attention. Good oral language skills have been shown to be the foundation for reading. Reading to young children is one of the best ways to develop their vocabulary, language, and background knowledge. Although speaking is an innate process, reading is not. There is no single location in the brain that serves as a "reading center;" rather, existing brain areas that serve oral language and object recognition must adapt to facilitate reading.[1]

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The Phonological Model of Reading

The most accepted model for development of reading ability is based on phonology. Phonemes are the smallest units of sound used to form words. They are coarticulated at 8-10 phonemes per second, with individual sounds

merging together. Reading requires the ability to hear, identify, and manipulate phonemes, and phonemic awareness is a prerequisite for learning phonics, an instructional approach that emphasizes understanding the relationship between the speech sounds and the letters of the alphabet. Early readers use phonics to decode written words; fluent readers, by contrast, automatically recognize words and can read connected text smoothly and with expression at a fast pace using larger units of print—syllables, roots, suffixes, and whole words. Reading comprehension is the ability to read text, process it, and understand its meaning. It is a complex active process that requires automatic decoding, vocabulary, listening comprehension, attention, working memory, inferential thinking, and general knowledge.[2]

Visual Functions Used in Reading

Reading involves the ability to see print, accommodate, converge, and perform a series of saccades and fixations. Young children have large accommodative amplitudes; their average amplitude of accommodation is 14 D, corresponding to a near point of accommodation of 2-3 inches. Thus, they can read comfortably at 6-7 inches for a prolonged time, because roughly 50% of their accommodative amplitude is available for sustained near activity, and their average refractive error is low (+1.00 to +2.00 D). The near point of convergence for most young readers is approximately 2 inches from the nose.[3]

Reading uses saccadic eye movements of short duration and high velocity. The mature reading pattern uses approximately 85% forward (rightward in English) saccades and 15% regression saccades. The saccade length depends on the ability to recognize letters, the length of the word before the saccade, and reading comprehension. Regression saccades are used for verification and comprehension and increase in number with increased difficulty of the text. They are also used to move to the start of the next line. Visual perception is suppressed during the saccades, while visual information is perceived during foveal fixations, which constitute 90% of reading time. Early readers and dyslexic readers use relatively shorter forward saccades, an increased number of regression saccades, and longer fixation times.[4]

Reading does not use smooth pursuit ("tracking") or the vestibular system. A visual acuity of 20/20 is not necessary to read; depending on grade level, a much lower visual acuity can suffice. Finally, children with visual disorders, including accommodative insufficiency (AI), convergence insufficiency (CI), saccadic initiation disorder, or nystagmus, can be successful readers.

Reading Difficulties and Dyslexia

Difficulty learning to read is common in the United States. In 2015 over 60% of students failed to meet national reading proficiency standards in both the 4th and 8th grades.[5] Difficulties in early reading may be caused by both experiential and instructional deficits. Problems such as attention deficit disorder/attention deficit hyperactivity disorder (ADD/ADHD), anxiety, depression, hearing loss, speech difficulties, low vision, high hyperopia or high astigmatism, CI, and/or AI may contribute to reading difficulties.

Nearly 20% of children have dyslexia, a neurologically based language-based reading disability.[6-8] Both anatomical and brain imagery studies have shown that there are differences in the way the brain of a person with dyslexia develops and functions. Children with dyslexia use different areas of the brain when reading as compared to "typical" readers, even before they start to read. Based on functional magnetic resonance imaging scans, typical readers have been found to predominantly use the inferior frontal (Broca) area (articulation, naming, and silent reading) and areas in the posterior brain: the parietal-temporal region (word analysis), the occipito-temporal area (word form and fluency) and the posterior inferior temporal cortex (word retrieval) in the left side of the brain. In contrast, readers with dyslexia show dysfunction in the left posterior areas and alternatively use pathways connecting the right occipito-temporal area and the bilateral inferior frontal gyri, and may also show weaker white matter connections.[9-16]

Dyslexia is a Language-Based Learning Disorder

Dyslexia is caused by a variation in language processing in the brain. Children with dyslexia typically show a deficit in phonological processing (an auditory processing problem involving hearing the sounds in speech). The phonological deficit leads to difficulty connecting speech sounds to letters, creating problems in learning to read, write, and spell.[3,6-8,10,17,18] Though a phonological deficit is the typical etiology for dyslexia, some children have multiple or alternative deficits, including deficits in oral language skills, sight word recognition (orthographic processing), processing speed, attention, verbal working memory, and/or comprehension.

Dyslexia is a lifelong condition that is both heritable and familial and is found slightly more frequently in boys than girls. It is unrelated to the child's intelligence or other cognitive abilities. It rarely occurs alone; other learning disabilities, such as dysgraphia (writing disability), dyscalculia (math disability), and dyspraxia (motor skill and coordination difficulties) often coexist with dyslexia. The comorbidity of ADD/ADHD, especially the inattentive type, and dyslexia occurs in 20%-40%. The prolonged psychological stress associated with dyslexia can often lead to poor self-esteem, anxiety and depression.[3,6-8,10,17,18]

Children with dyslexia processes information differently than most typical readers. They are often visual learners, with good visual-spatial skills, which may account for their success in art, architecture, science, technology, engineering, and math. As Sally Shaywitz, MD, has noted frequently, children with dyslexia have one area of difficulty in a "sea of strengths."

Signs of Dyslexia

In preschoolers, early signs of dyslexia may include difficulty developing speech and language, trouble learning nursery rhymes or playing rhyming games, confusing words that sound alike, mispronouncing words, and trouble recognizing letters. Young elementary school children with dyslexia often have difficulty learning the names and sounds of the letters, separating and blending sounds, sounding out words, recognizing sight words, and spelling. Although their math computational skills may be strong, they often have trouble with math word problems. These children often read slowly and dislike reading.[3,6-8,10,17,18]

Identification and Treatment of Dyslexia

The consequences of a slow start in reading accumulate over time, so it is critical to provide help and support before a student fails. To aid the early detection of dyslexia, teachers must undergo training in language concepts, reading theory and the signs of dyslexia. Students whose reading disability is identified and addressed in kindergarten or first grade have an approximately 90% chance of improving to grade level. In contrast, children identified after third grade have a 74% chance of continuing to struggle through high school. Ideally, it is important to identify and treat children before they leave third grade to have the best chance at academic success, but it's never too late. Testing should be used to make the correct diagnosis of the specific type of learning disability, strengths and weaknesses, and comorbid conditions in order to prescribe the proper therapeutic regimen.[3,6,10,17-20]

The Individuals with Disabilities Education Act 2004, Section 504 of the Rehabilitation Act of 1973, and the Americans with Disabilities Act define the rights of students with dyslexia. Students who qualify as having a specific learning disability are legally entitled to special services to help them overcome and accommodate their reading and learning problems. Students with severe dyslexia will usually qualify for special education, whereas, regrettably, many children with less severe dyslexia will never be properly diagnosed or treated.

Children with reading difficulties or reading disability need reading skills and the structure of language explicitly explained in patterns that are logical, systematic, and multisensory. Multisensory techniques involve the use of visual, auditory, kinesthetic, and tactile pathways simultaneously to enhance learning. The International Dyslexia Association calls multisensory evidence-based reading programs based on Orton-Gillingham techniques, the *Structured Literacy Approach*. Teaching phonemic awareness and "intensive systematic phonics" is the most efficient route to learning to read English for all students. Children are explicitly taught all of the spelling rules, how to blend sounds into words, and break words apart. Students should be taught specifically what to do when they encounter a new or difficult word. These programs also emphasize syllable instruction, the writing system, the architecture of words and word parts, sentence structure, word or phrase meaning, and grammar.[10,17-20]

Unfortunately, most classroom teachers are not yet trained in the scientifically based approaches effective for a child with dyslexia. Regular tutors and many special education teachers currently do not have the specialized training necessary to provide the specific type of remediation required for a child with dyslexia. These children often require an educational therapist or experienced, specially trained reading tutor in the Orton-Gillingham type approach. With proper interventions, people with dyslexia may learn to read accurately, but they typically have a persistent problem with fluency and continue to read slowly and nonautomatically throughout their lives.[10,17,18,20]

In addition to remediation, these children require the support gained from educational accommodations and tools, commonly including, extra time, testing alternatives, separate quiet room for testing, preferential seating, notetakers, recorded books, text-reading and dictation software, spellcheckers, and word-processing computers.[10,17,18,21]

Dyslexia is Not a Vision-based Learning Disorder

Many myths persist regarding dyslexia and vision. Most early readers and writers reverse some letters or words. However, children with dyslexia do not see letters or words upside down or backward. Problems with reading fluency are not due to "eye tracking problems"—children with reading problems often lose their place while reading, and skip words and lines because they struggle to decode or understand a letter or word combination, lack comprehension, or have difficulties with memory or attention. Difficulties with fluent reading are the result of reading difficulty and not the cause of the reading problem.[3,7,10,17,18]

The 2011 American Association of Pediatrics (AAP), American Association of Ophthalmology (AAO), American Association for Pediatric Ophthalmology and Strabismus (AAPOS), American Association of Certified Orthoptists (AACO) joint Technical Report on Learning Disabilities, Dyslexia and Vision states: "No consistent relationship between visual function and academic performance and reading ability has been shown. … 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." Ocular and vision problems may coexist with dyslexia, but are not more prevalent than in the general population.[3] Creavin and colleagues[22] reported that children with reading impairment have the same visual function as children without reading impairment. Although visual problems, including CI, can hamper reading, they are not the cause of reading disability.[3]

Non-evidence-based Vision Treatments of Dyslexia

Many non-evidence-based vision approaches for the remediation of reading difficulties exist. Irlen and colleagues[23] use tinted lenses and filters to treat those diagnosed with the "scotopic sensitivity syndrome" (not an actual medical syndrome), which is said to be a "visual perceptual problem" caused by glare and sensitivities to certain wavelengths of light. Behavioral optometrists use eye exercises, behavioral/perceptual vision therapy, and training glasses, usually covered under the rubric of vision training (VT).[24]

Behavioral optometrists believe that "visual efficiency problems" (strabismus and nonstrabismic binocular vision problems, such as CI or AI), and "visual information processing problems" profoundly contribute to reading difficulties. They also evaluate "saccadic movements" to detect "inefficient readers" while researchers have shown that the optometric developmental eye movement (DEM) test does not actually assess eye movements; moreover, other tests that developmental optometrists use are poorly validated.[3]

Optometrists define VT as a method to develop or improve visual skills and abilities. Orthoptic techniques are used to treat "visual efficiency problems," whereas "behavioral/perceptual" techniques are used to improve "visual processing," and inefficient readers are treated with "saccadic training methods." In addition to eye exercises, "training/developmental lenses," which are low hyperopic power (+.25 D to +.75 D) lenses with or without bifocals or low power prisms, patches, filters, electronic targets, balance boards, metronomes, computer programs, and other specialized instruments may be used. A VT program consists of in-office and at-home exercises performed over weeks to months.[24]

According to the joint statement on *Learning Related Vision Problems*, "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" (emphasis added).[25] However, the public expects this treatment to treat reading disability directly and may not understand this subtle disclaimer.

Despite the complete lack of corroborating research findings with methodological strength and statistical validity, VT and training glasses are widely available and directly marketed to parents and teachers for children who are experiencing learning difficulties. These methods rely on anecdotal evidence to convince the public that they work and often overstate the therapy's effectiveness and the types of problems they may address. Using VT may give parents and teachers the false sense that a child's reading difficulties are being adequately addressed. It could also critically delay remedial treatment that is most effective when started before the student reaches third grade.[26,27]

Not only are vision-related approaches misdirected in theory, but many authors of systematic literature reviews have concluded there is no scientific evidence of their efficacy to help children learn to read or improve their long-term educational performance.[3,28-32] Specifically, there is no valid evidence that colored overlays, training glasses, or the non-evidence-based components of VT prevent the development of visual disorders, allow children to be more responsive to educational instruction, or are an effective primary or adjuvant treatment for dyslexia or other learning disabilities. Use of these methods contradicts all evidence demonstrating that reading skills depend on language-based processes.[3]

The Role of the Pediatric Ophthalmologist

Pediatric ophthalmologists are often the first professional consulted when a child is experiencing difficulties learning to read or when VT has been suggested. Evaluation by a pediatric ophthalmologist can be valuable to determine whether there are eye or vision problems that could be interfering with learning or reading, and in treating them. Eye and vision problems occur in 5%-10% of early elementary students and 25% of high school students. Although eye and vision problems may coexist with dyslexia, they are not more prevalent than in the general population.[22] It is important to realize that vision problems, such as high hyperopia, CI, or AI may make reading at near very difficult and may occasionally masquerade as a learning problem or ADD/ADHD[3]; thus, in some cases once the vision problem is treated, the patient's attention and learning may improve.

A careful history can identify struggling readers even if a reading difficulty is not the presenting complaint for the

eye examination. Children with a past history of prematurity, language delays or articulation problems, or a family history of reading difficulties have a high likelihood of having reading problems. A general inquiry as to how school is going will often help direct the history. Children should be suspected of having dyslexia if they have shown difficulties learning their letters and their sounds, trouble sounding out words, slow reading, dislike of reading, difficulty with spelling or writing, prolonged time to complete homework, or have been diagnosed with ADD/ADHD. The ocular history should include nonleading inquiry to elicit any eye or vision complaints that suggest it is difficult for the child to read for extended periods of time. The examiner should recognize that children with dyslexia, whose eyes function normally, may present with visual symptoms. Also, healthy children may have visual complaints that arise from awareness of normal visual phenomena, such as physiologic diplopia and relaxation of accommodation. An inquiry regarding the child's use of near targets such as a laptop and handheld computers and games can provide information regarding the child's tolerance of near tasks.[3]

A comprehensive eye and vision examination of a struggling reader should rule out problems that could interfere with reading and provide treatment according to current standards of care. It is important to engage the child to obtain his or her full effort to maximize the accuracy of all portions of the examination. These children should read a short passage at their level to the ophthalmologist. Near visual acuity, accommodation, and convergence should be thoroughly assessed prior to cycloplegia and refraction.[3]

Although difficulty with accommodation is rare in children, it can cause blurring and discomfort at near. AI is typically associated with uncorrected high hyperopia, anticholinergic medications, anxiety, and can also be idiopathic. The monocular near point of accommodation can be measured with a small target brought closer to the face until the child complains of blur. The reciprocal of the near point is the accommodative amplitude. The accommodative amplitude can also be measured by introducing increasing minus power while reading at near until a complaint of blur is elicited, this can be performed with the phoropter. Dynamic retinoscopy assesses accommodation by measuring the diopters needed to neutralize the near retinoscopic reflex as the child, while wearing his habitual correction, focuses from distance to a near target. Accommodative facility is the ability to change focus to view targets presented at different distances (from board to paper and back, for example). It can be assessed by alternately applying –1.50D and +1.50D lenses in the phoropter or with "flipper" lenses while the child reads at near. An inability to maintain a clear image under these conditions is suggestive of accommodative infacility. Complaints of problems in the classroom when shifting focus from far to near and back may be due to symptomatic accommodative infacility, but often the cause is ADD/ADHD or the reading disability itself. AI can be treated with correction of hyperopia and/or bifocals/reading glasses.[3]

The diagnosis of CI requires both signs and symptoms. Symptomatic CI can cause discomfort, eyestrain, blurry vision, jumpy vision, diplopia, and headache. The near point of convergence should be tested 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 CI can be treated with home, computer or office-based orthoptic exercises. Reading glasses with base-in prism or monocular occlusion during reading can be used to alleviate the diplopia associated with CI.[3]

A careful examination should be performed to determine whether the child has ocular surface problems that may cause eye irritation or variable vision that could secondarily interfere with the ability to concentrate and learn. Finally, a cycloplegic refraction is crucial to determine the full and accurate refractive error. Glasses should be considered in these children if there is hyperopia of $\geq$+3.50D, astigmatism of $\geq$+1.50 D or anisometropia of $\geq$1.50 D.[3] Significant refractive error, accommodative difficulties, symptomatic CI, or external ocular problems can be treated and many will show benefit quickly. But, it is crucial to understand that although these treatments may improve visual acuity or relieve eye strain allowing longer more comfortable reading, they are not a treatment for coexisting dyslexia. If no eye or vision problem is detected, it should also be discussed, as ruling out a vision problem is also important.[3]

To ensure that children get appropriate timely care, pediatric ophthalmologists should have educational materials on dyslexia and lists of local resources where families can obtain evaluation and treatment. The International Dyslexia Association (IDA) and the National Center for Learning Disabilities are excellent primary resources for these families. The IDA Dyslexia Handbook: What Every Family Should Know,[17] the AAPOS patient education brochures and booklets on learning disabilities and dyslexia,[33] and the AAP ADD/ADHD brochure[34] provide information that ophthalmologists can use to educate families. The potential need for additional medical, psychological, educational evaluations should be discussed with the parents. A logical first step for a child with reading or learning difficulties is an evaluation by a psychologist or a neuropsychologist who performs educational evaluations. The ophthalmologist should inform all interested parties, including the primary care physician and the school of the ophthalmic findings and recommendations.

Pediatric ophthalmologists should also encourage parents to learn about the nature of their child's learning

difficulties, create a positive environment and support their child's reading efforts. Parents should identify their child's social, athletic, and academic strengths, and then find the time for their child to pursue activities that he or she enjoys.

In summary, dyslexia is a common and lifelong language-based learning disability. Early detection and intensive evidence-based instruction by skilled educators can improve reading for most children with dyslexia. Vision-oriented remedies such as training glasses, eye exercises, perceptual training, or colored lenses are ineffective primary or adjuvant treatments.

Pediatric ophthalmologists play a valuable role in assessing children who are experiencing difficulties learning to read. We are in a unique position to determine whether or not ocular or visual problems are contributing to poor reading, to educate parents regarding reading and dyslexia, to encourage early intervention, to describe evidence-based dyslexia treatment, and to provide guidance to find educational and treatment resources available online, in print, and in the community. Working together with parents and children, pediatric ophthalmologists can help formulate a prescription for a child's success in school and daily life.

References

1. Wolf M. Proust and the Squid—the Story and Science of the Reading Brain. New York, NY: HarperCollins Publishers; 2007.
2. Lyon GR. How do children learn to read? Adapted from: Lyon G R (July 10, 1997). Report on Learning Disabilities Research. Testimony before the Committee on Education and the Workforce, U.S. House of Representatives. Available at: http://www.readingrockets.org/article/how-do-children-learn-read. Accessed August 20, 2017.
3. Handler SM, Fierson WM, Section on Ophthalmology and Council for Children with Disabilities for the American Academy of Pediatrics, American Academy of Ophthalmology, American Association of Pediatric Ophthalmology and Strabismus, American Association of Certified Orthoptists. Learning disabilities, dyslexia, and vision: technical report. Pediatrics 2011;127:e818-56.
4. Rayner K. Eye movements and the perceptual span in beginning and skilled readers. J Exp Child Psychol 1986;41:211-36.
5. The National Assessment of Educational Progress (NAEP) The Nation's Report Card 2015 Reading Results. Available at: https://www.nationsreportcard.gov/reading_math_2015/files/infographic_2015_reading.pdf. Accessed August 20, 2017.
6. Moats LC, Dakin KE. Basic Facts about Dyslexia and Other Reading Problems. Baltimore: The International Dyslexia Association; 2008.
7. Lyon GR. Report on learning disabilities research. 1997. Available at: http://www.ldonline.org/article/6339/. Accessed August 20, 2017.
8. International Dyslexia Association Fact Sheets: Dyslexia Basics. Available at: https://dyslexiaida.org/dyslexia-basics/. Accessed August 20, 2017.
9. International Dyslexia Association Fact Sheets: Dyslexia and the Brain. Available at: https://dyslexiaida.org/dyslexia-and-the-brain-fact-sheet/. Accessed August 20, 2017.
10. Shaywitz SE, Shaywitz BA. The science of reading and dyslexia. J AAPOS 2003;7:158-66.
11. Shaywitz SE, Shaywitz BA, Pugh KR, et al. Functional disruption in the organization of the brain for reading in dyslexia. Proc Natl Acad Sci USA 1998;95:2636-41.
12. Shaywitz BA, Shaywitz SE, Pugh KR, et al. Disruption of posterior brain systems for reading in children with developmental dyslexia. Biol Psychiatry 2002;52:101-10.
13. Raschle NM, Zuk J, Gaab N. Functional characteristics of developmental dyslexia in left-hemispheric posterior brain regions predate reading onset. Proc Natl Acad Sci U S A 2012;109:2156-61.
14. Richlan F, Kronbichler M, Wimmer H. Meta-analyzing brain dysfunctions in dyslexic children and adults. Neuroimage 2011;56:1735-42.
15. Richlan F, Kronbichler M, Wimmer H. Structural abnormalities in the dyslexic brain: A meta-analysis of voxel-based morphometry studies. Hum Brain Mapp 2013;34:3055-65.
16. Rumsey JM, Andreason P, Zametkin AJ, et al. Failure to activate the left temporoparietal cortex in dyslexia: an oxygen 15 positron emission tomographic study. Arch Neurol 1992;49:527-34.
17. International Dyslexia Association. IDA Dyslexia Handbook: What Every Family Should Know. Available at: https://app.box.com/s/8ucxzz2u5wq2wezqoaqgrltn532z97bz. Accessed August 20, 2017.
18. Shaywitz S. Overcoming Dyslexia: A New and Complete Science-Based Program for Overcoming Reading Problems at Any Level. New York: Knopf; 2003.
19. International Dyslexia Association Fact Sheets: Dyslexia assessment—what it is and how can it help? Available at: https://dyslexiaida.org/dyslexia-assessment-what-is-it-and-how-can-it-help/. Accessed August 20, 2017.
20. International Dyslexia Association Fact Sheets: Effective Reading Instruction. Available at: https://dyslexiaida.org/effective-reading-instruction/. Accessed August 20, 2017.
21. Understood: At a Glance: Classroom Accommodations for Dyslexia. Available at: https://www.understood.org/en/school-learning/partnering-with-childs-school/instructional-strategies/at-a-glance-classroom-accommodations-for-dyslexia. Accessed August 20, 2017.
22. Creavin AL, Lingam R, Steer C, et al. Ophthalmic abnormalities and reading impairment. Pediatrics 2015;135:1057-65.
23. Irlen website. Available at: http://irlen.com/faqs/. Accessed August 20, 2017.
24. American Optometric Association Fact Sheets on optometric vision therapy. Available at: https://www.aoa.org/Documents/optometrists/vision-therapy-reimbursement-packet.pdf. Accessed August 20, 2017.
25. American Academy of Optometry and American Optometric Association. Joint Organizational Policy Statement Vision, Learning, and Dyslexia. Available at: https://c.ymcdn.com/sites/www.covd.org/resource/resmgr/position_papers/vision-learning-dyslexia_-_j.pdf. Accessed August 20, 2017.
26. Torgesen JK. Catch them before they fail—identification and assessment to prevent reading failure in young children. Am Educ;1-8. Available at: https://www.aft.org/sites/default/files/periodicals/torgesen.pdf. Accessed August 20, 2017.
27. Torgesen JK. Avoiding the devastating downhill spiral. The evidence that early intervention prevents reading failure. Am Educ. Fall. Available at: https://www.aft.org/periodical/american-educator/fall-2004/avoiding-devastating-downward-spiral. Accessed August 20, 2017.
28. Jennings AJ. Behavioural optometry: a critical review. Optom Pract 2000;1:67-78.
29. Rawstron JA, Burley CD, Elder MJ. A systematic review of the applicability and efficacy of eye exercises. J Pediatr Ophthalmol Strabismus 2005;42:82-8.
30. Barrett B. A critical evaluation of the evidence supporting the practice of behavioural vision therapy. Ophthalmic Physiol Opt 2009;29:4-25.
31. Fletcher JM, Currie D. Vision efficiency interventions and reading disability. Perspect Lang Lit 2011;37:21-4.
32. Ganivet A, Denault I, Superstein R, Fallaha N. The treatment of scholastic learning disabilities through the diverse visual therapy modalities: what is the scientific evidence? Can J of Optom 2014;76:15-22.

33. AAPOS Members Learning Disabilities Patient Information Package. Available at: https://aapos.org/members/resources/learning_disabilities_patient_information_/. Accessed August 20, 2017.

34. AAP Members Understanding ADHD Brochure. Available at: https://shop.aap.org/understanding-adhd-brochure-50pk-brochure/. Accessed August 20, 2017.

Amblyopia and slow reading

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Reading promotes imagination and learning, is fundamental to academic achievement, and relies on a complex interplay of visual and motor capabilities. Loss of the ability to read affects virtually all aspects of modern life, from school, to leisure, to the very activities of daily living. For optimal reading, text must be sequentially fixated by the fovea using coordinated, high-velocity, short-duration saccades. About 85% of eye movements during reading are *forward* saccades, with amplitudes of about 2°, or 8 letters of average-sized print text.[1] *Regressive*, or backward, saccades (15% of eye movements during reading) are used to recheck words, provide a second chance for decoding and comprehension, and move to the beginning of the next line of text.[2] Visual perception is suppressed during saccades, so word recognition and phoneme decoding occur during the *fixational pauses* that occur between saccades; these pauses constitute 90% of reading time.[1,3]

Using natural, binocular silent reading of age-appropriate paragraphs of text, we recently reported that children with amblyopia read slowly compared with controls and nonamblyopic strabismic children, regardless of amblyopia type (ie, strabismic or anisometropic).[4] Unlike earlier reading studies that focused on strabismus,[5-8] our study clearly identified that amblyopia alone is sufficient to impair reading. Importantly, comprehension did not differ significantly between amblyopic children and controls, indicating that amblyopic children did not read slowly because they had dyslexia or a learning disability.

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Dyslexia is a receptive language-based learning disability in which there is a deficit in the phonologic component of language that results in difficulties with decoding, fluent word recognition, rapid automatic naming, and/or reading-comprehension skills.[9] The increased duration of *fixational pauses* and increased number of *regressive* saccades that characterize dyslexic readers are direct results of decoding and comprehension difficulties rather than a primary abnormality of oculomotor control systems. Unlike dyslexic readers, amblyopic children in our study read more slowly because they made more *forward* saccades during reading. It is likely that the increased number of forward saccades during reading reflects oculomotor control system deficits. Amblyopia is associated with substantial fixation instability.[10-12] Fixation instability has been implicated in slower reading in normally-sighted[13] and visually impaired adults with macular disease, albinism, or glaucoma.[14,15] More recently, we reported that fixation instability, and an increased number of forward saccades was associated with slower reading in children with anisometropic amblyopia (Kelly, et al. J AAPOS 2017;21:e10 Abstract 024). Unstable fixation may make it difficult to plan and/or execute accurate forward saccades during reading. Additionally, similar to small central scotomas in macular disease, monofixation in amblyopia may reduce the visual span, resulting in poor saccadic accuracy and increased number of saccades during binocular reading.[16-18]

When a reader moves fixation forward to a new word, the preferred "landing position" is the center of the new word; other landing positions result in the word being processed more slowly and make it more likely that the word will be refixated with a corrective saccade.[19-21] In a visuomotor task requiring a saccade to a target dot prior to reaching and touching that dot, amblyopic adults exhibit greater variability in saccade amplitude and a higher frequency of corrective saccades compared with visually normal adults.[22,23] In addition, amblyopic adults lack the binocular advantage for saccade initiation that is present in visually normal adults who initiate saccades about 10% faster when viewing binocularly compared to viewing monocularly. Taken together, slower saccade initiation, saccade amplitude variability, and increased frequency of secondary saccades can be expected to significantly slow reading speed in amblyopic children.