Vision and learning

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 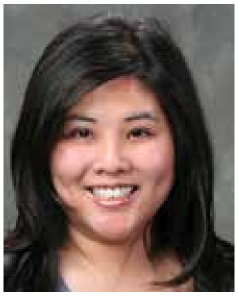

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Introduction

Visual impairment is one of the most prevalent chronic conditions of childhood and may affect educational achievement and self-esteem.[1–4] The Centers for Disease Control and Prevention (CDC) reported the prevalence of visual impairment and blindness among children <18 years of age to be 2.5%.[5] However, the number of children with reduced acuity is significantly under-represented as the CDC estimate is based on visual impairment defined by best-corrected visual acuity of 20/70 or worse in the better eye. Healthy People 2020 sets 10-year national objectives to reduce childhood prevalence of visual impairment through prevention, early detection, timely treatment and rehabilitation:[6]

- V-1 Increase the proportion of preschool children aged 5 years and under who receive vision screening
- V-2 Reduce blindness and visual impairment in children and adolescents aged 17 years and under
- V-5.1 Reduce visual impairment due to uncorrected refractive error

Identifying and managing refractive error is the first step in making sure a child is visually ready for school. Other conditions that have the potential to affect academic performance are disorders in vergence, accommodation, fine eye movements and visual perception. The purpose of this presentation is to detail how refractive error, visual efficiency and visual information processing disorders can interfere with the normal learning process.

Ametropia and Visual Impairment

It is estimated that over 80% of all visual impairment is treatable with refractive correction.[7] Among school-aged children there is a high prevalence of refractive error conditions which impact the quality of vision and, potentially, a child's ability to learn.[8,9] We are familiar with the notion that significant amounts of uncorrected refractive error can result in reduced acuity at distance and/or near. Hirsch originally reported this relationship between reduced acuity and uncorrected myopia and astigmatism.[10] Though the relationship is somewhat variable, a -1.00D uncorrected myopia can reduce distance acuity anywhere from 20/30 to 20/100. Langford and Hug reported that most visual demands in grades 3 to 5 ranged from 20/60 to 20/100.[11] The relationship between visual acuity and uncorrected hyperopia is more challenging to predict as it is dependent on the child's ability to use their accommodation to compensate for blur induced by the uncorrected hyperopia. However, high amounts of uncorrected hyperopia (> +3.00D) has been shown to increase a child's risk for the development of amblyopia and strabismus.[12–14]

Ametropia and Learning

Studies have found links between uncorrected refractive error and development. Atkinson et al., reported on the visual development of 9-month-old infants and found that those with significant amounts of hyperopia had modest yet consistently poorer performance on visual-cognitive and visual-motor tests as compared to age matched peers.[15] Rosner and Rosner corrected hyperopia in a cohort of children before their fourth birthday and found fewer delays in visual-motor skills as compared to hyperopic children that were corrected at a later date.[16]

Eames reported on 1,000 reading-disabled children and 150 controls and found a significantly larger prevalence of hyperopia among the reading-disabled children.[17] Shankar et al., found that within a sample of children with uncorrected hyperopia (+2.00D to +3.50D), performance on tests of letter and word recognition, receptive vocabulary, and emergent orthography (spelling) was less developed than in a cohort of children with emmetropia (+0.25D to +1.75D).[18] Williams et al., found that 8-year-old students, who failed a +4.00D fogging test and were confirmed to have hyperopia, scored lower on standardized assessment tests (English, mathematics and science) and the National Foundation for Education Research English test (reading and writing skills).[9] Although we assume that the increased accommodative demand results in a child's inability to optimally sustain near demands such as reading, this relationship has yet to be determined. In their meta-analysis, Grisham and Simons noted improved reading progress across studies when children received correction for hyperopia and anisometropia.[19]

In 1971, Grosvenor wrote, "Since there is evidence that hyperopes as a group may be less efficient readers than emmetropes or myopes, perhaps hyperopia warrants more study and emphasis than it has been given in the past."[20] Over 40 years later we are no closer to an evidence-based approach to the optimal correction of hyperopia as exhibited by the AOA Clinical Practice Guidelines, Care of the Patient with Hyperopia (revised 2008): "There is no universal approach to the treatment of hyperopia." In 2004, Lyons et al., published survey results from optometrists and ophthalmologists and found considerable differences in prescribing patterns among the professions of optometry and ophthalmology.[21] Cotter theorized that the differences may be due to the level of emphasis by some practitioners on areas such as accommodation, vergence and stereopsis, as well as symptoms and academic performance indicators.[22]

Visual Efficiency and Learning

The ability to see better than 20/40 has often been the defining criteria to determine adequate vision for school.[23] However, visual acuity is not the only aspect of vision that may affect academic performance; oculomotor, accommodative and vergence skills can also impact a child's learning. Poorer readers have been found to have an increased number of fixations, higher number of regression saccades, and longer duration of fixation as compared to normal readers.[24] Lefton et al., observed that these inefficiencies did not naturally improve over time in students characterized as poor readers.[25] Kulp and Schmidt found that incorporating stereoacuity and accommodative facility testing as a supplement to the Modified Clinical Technique (MCT) vision screening battery was predictive in identifying successful or unsuccessful readers in a group of kindergartners and first graders.[26] Quaid and Simpson found a greater prevalence of hyperopia and reduced vergence facility among a cohort of children who were struggling in school.[27] Vergence facility in particular was correlated with reading speed and the number of fixations made when reading. Convergence insufficiency (CI) is a common binocular vision disorder that is defined by a constellation of findings: greater exophoria at near than distance, reduced near point of convergence and reduced compensatory positive fusional vergence.[28] Rouse et al., found the prevalence of CI with all three findings to be 4.2% among school-aged children (10-12 years old).[29] Children suffering from CI often report a higher frequency of symptoms that include loss of place, slow reading and poor concentration when reading as compared to children with normal binocular vision.[30] Children with symptomatic CI also report a significantly higher number of academic performance symptoms (e.g., difficulty completing assignments, inattentiveness and avoidance of reading) when compared to children with normal binocular vision.[31]

Case series and literature reviews have reported compelling arguments for the impact that vision therapy has on the improvement of the signs and symptoms of oculomotor, accommodative and vergence disorders and its secondary impact on academic performance. The most definitive study on the effectiveness of vision therapy, Convergence Insufficiency Treatment Trial (CITT), reported that 12 weeks of office-based accommodative and vergence therapy with home reinforcement significantly improved the signs and symptoms of CI as compared to home-based treatments and placebo therapy.[32] Atzmon et al., randomized a group of reading-disabled children into reading therapy and vision therapy. Although their study lacked a control group, both interventions were found to improve reading performance with the additional benefit of less asthenopia in the vision therapy group.[33] In the CITT study, Borsting et al., reported that improvement in signs and symptoms of CI resulted in a reduction of the frequency of adverse academic behaviors and parental concern associated with reading and school work.[34] Although it has been hypothesized that the treatment of visual efficiency disorders reduces the labor of reading, thereby improving reading performance, this cause and effect has yet to be proven. Currently, there is a National Eye Institute funded study, CITT-ART, looking at the relationship of the effect of CI treatment on reading and attention.

Visual Information Processing and Learning

Visual information processing skills, also referred to as visual perceptual skills, are important to consider when examining children. These skills integrate with higher cognitive skills and other sensory modalities in order to give meaning to what is seen and is important for activities like reading. Visual perceptual skills can be further categorized as visual spatial, visual analysis and visual-motor skills. Visual spatial skills help us to understand directional concepts like up, down, left and right and how these directions relate to our body and other objects in space. These fundamental skills are essential for navigating the world, understanding directions and are also important when learning linguistic symbols (e.g., b, d, p, q). Visual analysis skills are used to analyze what is seen, remember what is seen, to visualize what is seen, and to do these things efficiently. Visual-motor skills, also referred to as eye-hand coordination skills, integrate visual information with motor skills and are important when writing and copying information.

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Studies have shown evidence of a relationship between visual perceptual skills and learning. Solan et al., found correlations between visual spatial, visual analysis and visual-motor skills with reading readiness and written and mental arithmetic.[35,36] In a meta-analysis by Kavale, visual perception was found to be related to reading and it was suggested that visual perceptual skills such as visual discrimination, visual memory, visual closure, visual figure ground and visual-motor integration be considered along with other factors as predictors for reading achievement.[37] Kavale stated, "visual perceptual skills, when considered both individually and in combination, accounted for moderate proportions of the total variance in reading ability." Multiple studies have shown the speed of processing as an important skill that can differentiate good readers from poor readers.[38–42] Visual-motor skills have also been found to be related to academic achievement.[43,44] For example, Barnhardt et al., found that poor visual-motor integration contributed to poor spatial organization of written work as demonstrated by increased errors with alignment of numbers in math problems and spacing errors of letters and words.[45]

Studies have shown the effectiveness of vision therapy in improving visual perception skills also benefits student's receptiveness to academic instruction. Greenspan showed a statistically significant improvement in visual spatial skills and a reduction in reversal errors in children who received visual spatial therapy compared to those in a control group who received orthoptic (vergence) therapy.[46] In a retrospective study by Tassinari and Eastland, those that received perceptual therapy showed an improvement in visual-motor test scores and a reduction in symptoms associated with deficient visual-motor integration.[47] Attention therapy has also been shown to have a significant impact on reading speed, accuracy, and comprehension.[48,49] Seiderman provided perceptual therapy to learning-disabled children and demonstrated an improvement on specific subtests of the Stanford Achievement Test as compared to the control group.[50] It is important to keep in mind that visual perception disorders hamper classroom performance and may contribute to a learning problem, but it does not cause a learning disability.

Conclusion

It is estimated that as much as 80% of what a child learns is acquired through vision, hence vision is essential to a child's ability to learn and reach their academic potential. As children progress in school, they encounter higher and higher visual demands. These visual demands are not only in acuity as size of print becomes smaller, but also with increased crowding effects as there are more words on the page and less pictures. These demands require more precision in saccades as well as the ability to distinguish the figure from the ground (the trees from the forest is a common analogy). A child's accommodative and vergence stamina are challenged with greater amounts of homework and with a greater presence of technology usage. Some children are able to perform these tasks without any manifestations of symptoms, whereas others struggle with symptoms of fatigue, eyestrain, headaches, or academic performance that does not match their level of effort. So the next time a child walks into your exam room, prescribing the correct spectacles may not be the only help you can provide. Rather, consider all aspects of their vision as you can play an important role in a child's academic success.

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