Vision and Reading

When a person reads print, there is an obvious component that involves vision. Reading visually presented material requires adequate acuity, meaning that the letters and words stand out crisply and clearly because the eyes are well focused and accommodate accurately on the materials of interest. The two eyes must also work together to converge properly to the material, and ocular motility enables the eyes to coordinate movements and track the words across a page.

The brain, of course, is also involved in reading. There are two parallel visual systems in the brain: magnocellular and parvocellular. The magnocellular pathway supports peripheral vision, which is necessary for detecting motion to one’s side. But to identify what is moving in the periphery, one needs central vision. If something is moving to our side, we make a quick eye movement (saccade) and then turn to face it so we can see what it is. Central vision is supported by the parvocellular visual pathway, which allows us to recognize visual objects, whether they are faces, cars, or printed words. As discussed later in this article, it is much less clear why the magnocellular system would be important for reading. Finally, the vision systems interact with higher cortical systems that process spatial material and guide motor movements, such as the eye movements in reading. A key point is that normal eye movements are guided by the information requirements of higher cortical systems. Where we look next in a line of text is determined by what is perceived in the visual span ahead of the fixation point and how well we understand what we have just read. If the word we just read doesn’t make sense, our eyes move back to read it again or even go back to the words that preceded it.

Not surprisingly, at different periods over the past century, all these aspects of the visual system—from difficulties with visual acuity and convergence, coordinated eye movements, the magnocellular system, and visual-spatial and visual-motor processing—have been invoked as causes of reading disability. Children with learning disabilities are often referred to eye care or other professionals for various controversial therapies such as tracking therapies, “special” lenses and colored overlays, and interventions to train spatial and visual-motor skills. We support the benefits of a comprehensive eye exam to assess a child’s visual functioning and provide management for any refractive, accommodative, or binocular anomaly present to allow clear, comfortable binocular vision for near work. However, while having adequate visual functions may make reading more comfortable, it “does not directly improve decoding or comprehension” as reported in a joint statement on vision and learning disabilities (including the American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, Council on Children with Disabilities, American Association of Certified Orthoptists; American Academy of Pediatrics, 2009).

The approach supported by the American Optometric Association (AOA) is that if a deficit in a vision-related process is identified, the deficit itself should be treated. The AOA guidelines state that “the goals of optometric intervention should be specific and problem oriented, rather than indefinite such as to improve school performance.” They recommend a multidisciplinary approach: “educators, psychologists, optometrists and other professionals must confer and work together to meet each child’s needs.” Yet a number of the therapies included in the AOA guidelines expand to domains involving auditory-visual integration, laterality and handedness, and executive function, and are claimed by some behavioral optometrists (a growing subspecialty of optometry) to help children with learning and reading disabilities. Other therapies utilized by behavioral optometry include eye movement/tracking therapy (supported by the AOA), and some therapies not explicitly recommended by the AOA such as yoked prisms (weak prisms used to shift images to both eyes the same direction and amount, typically up or down, as opposed to yoked prisms prescribed for eye muscle imbalances or visual field loss), certain types of low plus add devices (very weak reading glasses that do not significantly alter the focusing demands but purport to reduce near point stress, as opposed to standard reading glasses that help reduce focusing demands and/or excessive convergence problems), and syntonics (a form of phototherapy). In addition, other professionals (educators and psychologists) have also claimed a benefit from the use of colored overlays or tinted lenses.

In this article, we review some of the theories and findings underlying visual efficiency explanations of reading disability, noting beforehand that these explanations lack the evidence that supports explanations of reading difficulties based on language processes. We also review evidence of the efficacy of some of these visually-based interventions, but we do not review visual information processing because there is a strong research base that indicates that spatial cognition and visual-motor skills are not strongly linked to learning disabilities (Pennington, 2009; Vellutino, 1979; Vellutino, Fletcher, Scanlon, & Snowling, 2004). In addition, there is little support for the efficacy of interventions based on visual information processing as defined in the American Optometric Association’s practice guide (Garzia et al., 2008), largely because they do not lead to improved reading or academic performance (Mann, 1979; Humphries, Wright, Snider, & McDougall, 1992).

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Visual Processing and Reading Disability

Theories involving vision and reading disability have focused largely on sensory level vision processes and oculomotor mobility (eye tracking). In the American Optometric Association’s practice guide (Garzia et al., 2008), these areas are listed under “visual efficiency” and are subject to evaluation and treatment by behavioral optometrists. However, “visual efficiency” also includes the mainstream optometric assessments of visual acuity, refraction, binocularity, and accommodation (which involve ensuring that objects are single, sharp, and clear). The guidelines emphasize the heterogeneous nature of learning disabilities, identifying symptoms that range from academic problems to poor impulse control, and social difficulties. In addition, “many individuals have mild or constrained learning problems that are not of sufficient magnitude to be classified formally as learning disabilities; nevertheless, they may have significant learning related vision problems (p.5).”

Visual Efficiency

Interventions treating visual efficiency are usually based on the idea that presensory visual problems interfere with the ability to easily perceive text. There is an extensive literature evaluating visual persistence, contrast and flicker persistence, eye movements and saccadic suppression, and the detection of motion, usually in children and adults described as “dyslexic” (Boden & Giaschi, 2007; Rayner, Pollatsek, & Bilsky, 1995; Stein, 2001). Comparing groups of people with and without dyslexia often shows deficiencies on these types of tasks, which are then related to the functioning of the magnocellular system or to some aspect of oculomotor control (Lovegrave, Martin, & Slaghuis, 1986; Stein, 2001).

Magnocellular deficits. Boden and Giaschi (2007) identified multiple potential manifestations of magnocellular functions that might disrupt reading, including deficits in 1) contrast sensitivity; 2) position encoding of letters in a word; 3) oculomotor deficits that affect eye movement control of saccades or binocular control; and 4) foveal/parafoveal interactions that lead to sluggishness in temporal processing. Like other reviews of this area, Boden and Giaschi find conflicting support for each of these possibilities, but note that the research base does not firmly establish a role for the magnocellular system in reading, much less in reading disability. Other reviews are more negative, with Skottun and Skoyles (2008) stating that “as far as vision is concerned there is little evidence for a specifically temporal deficit.” This review included studies of visual persistence, temporal order judgments, and coherent motion, as well as contrast sensitivity and temporal acuity. Ramus (2003) acknowledged that presensory visual deficits (and auditory processing deficits) may be seen in people with dyslexia, but occur at relatively low rates and seem to have limited capacity for explaining the actual reading difficulty. In particular, there is little evidence that visual (or auditory) presensory processes explain both the reading and the phonological processing difficulties robustly identified as major correlates of dyslexia (Olson & Datta, 2002; Vellutino et al., 2004).

Ocular motor mobility and binocular control. In terms of eye movements, Rayner et al. (1995), among others (Kirkby, Webster, Blythe, & Liversedge, 2008), have found that the eye movement difficulties seen in children with dyslexia are the product of their proficiency in reading as opposed to a cause of their reading problems. In evaluating the binocular control literature, Kirkby and her co-authors concluded that “From the studies reviewed here, it should be clear that results in this area are highly contradictory (p. 757).” There is no firm evidence of eye movement difficulties associated with reading problems that aren’t explained in terms of the person’s level of reading proficiency.

Orthographic processes. Recent efforts have related visual processing to specific difficulties in processing orthographic patterns of words, representing an alternative approach to explaining word recognition difficulties that are more tied to visual than phonological and linguistic processes clearly associated with word recognition. Although some studies have found that orthographic coding correlates with different aspects of visual efficiency (e.g., Talcott et al., 2000), these relations have not been specific to children and adults with reading difficulties. Moreover, it has not been demonstrated that orthographic processes are more strongly related to word reading than phonological processing.

Scotopic sensitivity syndrome. One other visual hypothesis that is also based on the magnocellular system has been institutionalized as “scotopic sensitivity syndrome,” for which color lenses and overlays are used to improve the efficiency of visual processing of text. Like other visual efficiency hypotheses, scotopic sensitivity (or Irlen) syndrome is hypothesized to be a visual efficiency problem that affects individuals with or without reading disabilities. The claim is that this problem makes reading difficult because it degrades or jumbles the perception of print, and that colored filters, either lenses or overlays, improve the functioning of the magnocellular system and prevent letters and words from seeming to jump around the page. Most of the evidence addressing this hypothesis comes from intervention studies, discussed below, as opposed to direct evaluations of the hypothesis. Some surveys suggest that symptoms of scotopic sensitivity syndrome are common (Evans & Joseph, 2002).

Interventions for Visual Efficiency Difficulties

Given the difficulties in establishing consistent support for hypotheses involving deficiencies in visual efficiency, including vision problems derived from the magnocellular system as well as oculomotor control hypotheses, it is not surprising that there is little support for the efficacy of interventions based on these deficiencies. A review paper commissioned by the United Kingdom College of Optometrists (Barrett, 2009) concluded that “Although there are areas where the available evidence is consistent with claims made by behavioral optometrists... a large majority of behavioral management approaches are not evidence-based, and thus cannot be advocated.” This review included studies of 1) vision therapy for accommodation and
convergence disorders; 2) low magnitude yoked prisms; 3) near point stress and low-plus prescriptions; and 4) behavioral treatments for myopia, strabismus, amblyopia, and peripheral awareness usually outside mainstream optometry. The review did not address the use of colored lenses and overlays, noting that such interventions were not the exclusive province of behavioral optometrists.

In the consensus statement organized by the American Academy of Pediatrics (2009), the conclusions of an extensive literature review indicated little evidence supporting explanations of reading disabilities based on either visual efficiency or visual information processing, and little evidence outside of treatment for convergence insufficiency (not strongly related to reading difficulties) that such difficulties can be treated. Even in areas supported by evidence that the vision-related problem could be corrected (e.g., accommodation), the review noted that evidence linking problems with visual efficiency to achievement, reading, attention, and other domains of adaptive functioning were not supported by controlled clinical trials. The consensus stated “Numerous studies have shown that children with dyslexia or related learning disabilities have the same visual function and ocular health as children without such conditions. Specifically, subtle eye or visual problems, including visual perceptual disorders, refractive error, abnormal focusing, jerky eye movements, binocular dysfunction or crossed eyes, do not cause dyslexia” (p. 839). Moreover, “Scientific evidence does not support the efficacy of eye exercises, behavioral vision therapy, or special tinted lenses or filters for improving the long-term educational performance in these complex pediatric neurocognitive conditions (p. 837).”

The concerns about colored lenses and filters echo concerns of previous reviews (e.g., Wilsher & Taylor, 1987) and are noteworthy because of efforts by proponents of these interventions to introduce legislation mandating screening for scotopic sensitivity syndrome in different states, some of which (e.g., Arizona) actually passed laws requiring such screening. These interventions have been studied for many years, but there are few well-controlled studies of efficacy that demonstrate improvements in reading that are specific to children with reading difficulties. Many current studies find inconsistent evidence for small and questionably clinically significant increases in reading rate, but little evidence of measurable effects on accuracy or comprehension, or effects that indicate specific improvement in children with reading disabilities (Iovino, Fletcher, Breitmeyer, & Foorman, 1998; Bouldoukian, Wilkins, & Evans, 2002; Lawton, 2008; Christenson et al., 2001).

Conclusions

Multiple factors make this research base on visual efficiency and reading disability contradictory and unclear. Prior to evaluating interventions, a clear role for low-level vision processing in reading needs to be established (Boden & Giaschi, 2007; Skottun & Skoyles, 2008). These studies should be carried out in a multivariate framework with inclusion of dependent variables clearly related to poor reading (e.g., phonological awareness) to assess the unique contributions of vision-related variables. Most studies of vision processes are univariate, that is, they evaluate a single dependent variable. Comparisons of children with and without reading disabilities almost always yield a significant difference if the sample is large enough. Across multiple attributes, dyslexia and other reading disabilities are dimensional, existing on a continuous distribution with no qualitative break points indicating where on the distribution dyslexia may occur. Selecting on the basis of an attribute (reading) and comparing on a correlated variable, such as visual perceptual skills, almost always yields a statistically significant average difference if the sample is large enough. From this significant difference, some researchers extrapolate a causal relation even though the relation is inherently correlational. In a seminal paper, Donald Doehring (1978) referred to this phenomenon as “a tangled web of research” on dyslexia.

Another factor to consider is that many of the studies of visual efficiency vary in the definition of reading disability, both in terms of selection criteria as well as the type of reading measure used to define poor reading. Dyslexia per se must be defined at the level of accuracy and/or fluency of reading single words. It is also possible to define other kinds of reading difficulties that occur at the level of the text (fluency, comprehension; see Fletcher, Lyon, Fuchs, & Barnes, 2007; Pennington, 2009), but these kinds of reading problems should not be confused with dyslexia, the most prevalent form of reading disability.

Perhaps most important, when dyslexia is understood as a word-level problem, it is unclear how the magnocellular system could be invoked as an explanation of word recognition deficits (Hulme, 1988). Studies of the effects of overlays show no evidence of improvements in single word reading (Lovino et al., 1998), which is not surprising because the magnocellular system operates as a person reads continuous text. Similar issues relate to eye movements and binocular control. Thus, the magnocellular system has no involvement in reading isolated words, the core deficit in dyslexia.

Recommendations

Given the evidence in this article and other reviews (American Academy of Pediatrics, 2009; Barrett, 2009), children with academic problems should be referred for vision exams using the same criteria as any other child. Visual acuity is critical for supporting reading, and people need to be able to see print sharply, clearly, and comfortably. However, routine screening for “vision-related learning problems” is not warranted and would not be expected to have a major impact on the reading performance of children and adults with well-defined reading disabilities. Although there are claims for average improved reading rates and comprehension in people who use colored lenses or overlays, these results are inconsistent, small in magnitude, and not specific to people with reading difficulties. It is possible that vision-related difficulties are a correlate of learning disabilities and may provide clues to individual differences in brain function, especially since many people with learning disabilities have problems not directly related to academic skills. It may be that vision efficiency interventions make a person more comfortable with reading. However, there is little evaluation of whether even the experience of more comfort carries over to the classroom or is a sustained practice. In many respects, the literature on vision

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efficiency therapies is reminiscent of the literature on other process-based interventions (e.g., visual-spatial and visual-motor skills), where the person may improve in task specific spatial processing or motor skills, but there is little generalization to stronger academic skills. Interventions tend to be effective for what is actually trained and pervasive effects outside the domain of intervention are rarely apparent. If the goal is improved reading or math, teach reading and math, and prioritize resources in the domain of interest. Referral for color overlays, tinted lenses, eye tracking, and visual information processing interventions are not supported by research.

The fact that vision therapies (and therapies based on visual information processing) continue to proliferate despite decades of research reflects in part the degree to which parents are desperate to remediate reading problems. In addition, on the surface, such interventions can be implemented relatively easily, and they promise success that seems supported by the measurable improvements in the specific task being trained. Unfortunately, the continued availability of these kinds of interventions reflects the more general problem of how evidence is adjudicated in education. Strong claims about efficacy are often accepted on the basis of anecdote, personal experience, and poorly controlled experiments. Sadly, many educational programs are not subjected to similar levels of scrutiny. Until education truly resolves to base decisions on adequate science, including controlled clinical trials, these problems are likely to continue to the detriment of children and our educational system.

References

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