Dyslexia: An overview*

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ABSTRACT

Dyslexia is a neuro-developmental disorder characterized by difficulties in learning to read despite conventional instruction, adequate intelligence and a balanced sociocultural background. Dyslexia is the most common type of learning disorder. Reading difficulties affect a child's academic achievement. As primary eye care practitioners, optometrists have a role in attending to patients who may present with symptoms indicative of dyslexia, therefore an understanding of dyslexia will be beneficial to the optometrist. This paper presents an overview of dyslexia and discusses its prevalence, aetiology, classifications, neural pathways involved in reading, theories, neuro-imaging techniques and management options. The role of optometry in the multidisciplinary management of dyslexia is discussed.

Keywords: dyslexia and optometry, learning disability, reading difficulties

Introduction

Some children find it difficult to learn to read despite having normal intelligence, appropriate educational opportunities and absence of emotional disorders. These children have a reading age that is two or more years behind their chronological age and have dyslexia. The term dyslexia is used synonymously as developmental dyslexia and as specific reading disability (specific indicating that development is normal except for reading).[1-3] It is derived from the Greek words: 'dys' meaning hard or difficult and 'lexia' from the word 'lexicos' which means pertaining to words; so dyslexia means a difficulty with words.[4]

Brief Historical Perspective

Historical accounts on dyslexia vary but dyslexia was originally described as 'word blindness'.[5] But according to Chakravarty,[6] the term dyslexia was first introduced by a German Physician, Berlin in 1887. Habib[7] reported that the concept of the neurological basis of dyslexia was first mentioned independently

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by a Scottish ophthalmologist, James Hinshelwood in 1895 and a British physician, Morgan in 1896. However, as cited by Cardinal *et al,*[8] Samuel Orton, (a neuro-psychiatrist) in 1927, theorized that the lack of development of cerebral dominance lead to a 'directional confusion' example, "d" instead of "b" and introduced the word 'strephosymbolia' meaning twisted symbol.

The approaches in dyslexia are diverse and Frith[9] noted that this probably may have been compounded by the fact that discussions on dyslexia involves three levels of description; behavioural (difficulty with reading and writing), cognitive (information-processing mechanisms) biological (neuro-anatomical and genetic) with all three levels being influenced by environmental factors. Secondly, the literature on dyslexia contains numerous studies conducted over the years from different disciplines including psychology, medicine, neuroscience and education. Kristen *et al*[10] noted that the heterogeneous nature of dyslexia is a major contributory factor to the differences in experimental results and conclusions.

An inability to read and comprehend is a major obstacle to learning, which may have long-term educational, social, and economic consequences. Vision plays a major role in the reading process and optometrists often receive concerns from parents who may think that their child's poor performance at school may be vision-related. Furthermore, due to the important role of reading and literacy, researchers have attempted to understand the nature and causes of dyslexia with the ultimate goal of developing appropriate treatments and interventions. This paper provides an overview of the basic concepts of dyslexia and discusses the prevalence, etiology, classifications, neural pathways involved in reading, components of reading, imaging techniques in dyslexia, social and emotional consequences of dyslexia as well the management options.

Definitions

Dyslexia has been defined in different ways by different authorities but three commonly cited definitions include those given by the World Federation of Neurologists in 1968 as:

> *a disorder manifested by difficulty in learning to read, despite conventional instruction, adequate intelligence and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities, which are frequently constitutional in origin.*[4]

In 2003, this definition was expanded to:

> *a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge.*[11]

Thirdly, according to the British Dyslexia Association (BDA),

> *dyslexia is a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling and writing. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, organization, sequencing, spoken language and motor skills. There may be difficulties with auditory and/or visual perception. Dyslexia can occur despite normal intellectual ability and education opportunity. It is constitutional in origin, part of one's make-up and independent of socio-economic status.*[12]

Although definitions vary, there seems to be a consensus regarding the linguistic basis of dyslexia.

There is a difference between dyslexia and general reading disabilities. Dyslexia is a mild neurological disorder that causes a deficit affecting an individual's ability to interpret the symbols of written language, and it is independent of intelligence.[8] General reading disability (non-specific reading disability), on the other hand, is a secondary reading disorder that is due to factors such as low intelligence, educational deprivation, socio-cultural deprivations, primary emotional problems, sensory impairments, poor motivation, or attention problems.[8,13,14]

Reading

Reading is the process of extracting meaning from written text[2] and it is a fundamental aspect of learning and education of a child. Learning to read is coordinated by a complex system of skills and involves a variety of behaviors such as letter naming, letter perception, word recognition and comprehension,

each of which uses a different part of the brain.[1,15,17] There is now some consensus that irrespective of the contributions of other systems, dyslexia is a language-based disorder characterized by difficulties in reading, spelling and writing, in which the core difficulty in reading difficulty manifests as a deficiency at the level of phonological processing abilities within the language system.[1,5,18] The main area of difficulty lies in coding ability that involves decoding (determining the sound of a word from the printed symbols) and encoding (determining the letters which form the written word from a dictated word), both terms also referred to as recognizing and spelling respectively.[8] Interestingly, dyslexics may not have overt difficulties with spoken language, yet do have marked difficulties with written languages.[19] The difference between written and spoken language is that written word is seen while spoken language is heard. The fact that print is seen may explain why vision has always been associated with dyslexia.[19]

Dyslexia, a developmental disorder that shows in different ways at different developmental stages,[4,20] is a life-long difficulty and its nature changes with maturation and development; symptoms that are present at one point in development may not be evident at another, and often some deficits are compensated for as the individual grow older.[21] Dyslexics are unique; each having individual strengths and weaknesses. Although most of the literature on dyslexia focuses on its difficulties, many dyslexics are in fact creative, talented and are successful in a variety of disciplines such as arts, law, medicine, science, business and education.[6,22-24]

Dyslexia is primarily not a problem of defective vision, although an underlying vision deficit has been known to exaggerate the reading problems[19] by impeding the dyslexic individual's ability to respond to educational intervention.[25] Dyslexia is frequently found with other neuro-developmental disorders, such as specific language impairment (oral communication disorder) and attention deficit hyperactivity disorder.[26,27]

In some cases, even when a clear visual image is presented, a dyslexic child may find it difficult to read and make meaning of the printed word.[1,5] This may be related to the fact that the difficulty that dyslexics have is at a fundamental (lower-order) stage in the reading process; a deficit in a lower-order linguistic function prevents access to higher-order processes and to the ability to draw meaning from text. The problem is that the person is unable to use his or her higher-order linguistic skills to access the meaning until the printed word has first been decoded and identified.[1,5] The two main situations in which the term dyslexia now commonly applies are; when the reader has difficulty decoding words (that is, single word identification) and the second is encoding words (spelling). The second type is a frequent presentation in optometric practice that is when the reader makes a significant number of letter reversal errors, letter transposition in word when reading or writing (for example, sign for sing) or has left-right confusion.[28]

Prevalence

Dyslexia is the most prevalent and the most researched type of learning disability affecting about 80% of all those identified as learning-disabled.[29] The reports on the prevalence of dyslexia in the literature vary. Estimates of the prevalence in school-aged children in the United States of America ranges[29] between 5 to 17%. In the United Kingdom, the prevalence ranges[30-31] between 3-6%. Dyslexia was thought to affect boys and girls comparably[29] but some studies[32-33] reported dyslexia to be more prevalent in boys than girls. A review of four large-scale epidemiological studies by Rutter *et al*[34] concluded that dyslexia is substantially more common in boys than in girls.

The large variability in the prevalence of dyslexia reported by different authorities may be attributed to the differences in the diagnostic criteria and definition,[35] age, language and culture.[3] The prevalence rates cited above are for English speaking countries. In Chinese and Japanese, the prevalence of dyslexia is reported[2-3] to be as low as 1%. This difference in prevalence rates in different countries therefore, raises an issue of cultural differences in dyslexia. A reason for the low prevalence rates in Chinese and Japanese compared to the prevalence in English language is that the English language has an opaque (or deep) orthography (writing style) in which the relationships between letters and sounds are inconsistent. Hence, the English language (that uses alphabetical system) presents more challenge to the beginning reader than other more regular languages such as Chinese and Japanese that contain consistent mappings between letters and sounds and are described as transparent (or shallow orthographies).[2-3] Furthermore, the neural circuits involved in reading and reading disorders may vary across languages because of differences in how

a writing system links print to spoken language,[16] as revealed by functional neuro-imaging techniques.

Information on the prevalence of dyslexia in most African countries including South Africa was not available. However, the prevalence of specific reading difficulty in 2nd and 3rd grades in elementary school population in Egypt was reported to be 1% and the male to female ratio to be 2.7 to 1. The authors concluded that the prevalence was low compared to that reported in western countries and that the difference may be because of the way Arab language is written and read.[36]

Signs and Symptoms

Dyslexic individuals experience a range of relative quantifiable symptoms. Dyslexia is heterogeneous in nature[9,37] and there is no single pattern of difficulty that affects all people, and not every symptom of dysfunction is found in every dyslexic child. Children who are dyslexic frequently show a combination of one of a variety of characteristics.[1,11,14,28,38-39] During reading, the following signs and symptoms may be noted in dyslexic children: word reversals, skipping of words, re-reads lines, points to words, word substitution, diplopia, poor comprehension in oral reading, might see text appearing to jump around on a page, unable to tell difference between letters that look similar in shape such as o and e, unable to tell difference between letters with similar shape but different orientation such as b and p and, letters might look all jumped up and out of order. Furthermore, letters of some words might appear completely backwards such as the word bird looking like drib.[1,11,14,38-39] Spelling difficulties (dysgraphia) include omission of beginning or ending letters, can spell better orally than written.[1,11,14,38-39] In addition, dyslexic children have difficulty with numeric association (dyscalculia). The difficulties specifically related to reading include: difficulty learning to read, difficulty identifying or generating rhyming words, or counting syllables in words (phonological awareness), difficulty with manipulating sounds in words, difficulty distinguishing different sounds in words (auditory discrimination).[1,11,14,38-39] Verbal symptoms associated with dyslexia are faulty pronunciation, difficulty acquiring vocabulary, difficulty following directions, confusion with words such as before/after, right/left, difficulty with word retrieval, difficulty understanding concepts and relationships of words and sentences.[1,11,14,38-39] Finally, non-linguistic difficulties include problems with co-ordination of eye movements, poor motor control (dyspraxia) and problems with early sensory processing.[26,38]

Dyslexics may also be susceptible to social and emotional problems, which are invariably due to the gross difficulty in learning to read, write and comprehend in some cases and are often related to their inability to meet expectations.[40] Furthermore, the dyslexic child may experience anxiety, anger, lowered self-image and depression,[26,40] which may affect the overall well-being and academic achievements of the child.

Diagnosis

The diagnosis of dyslexia may involve dyslexia screening which is a relatively simple, quick method of indicating whether a child might have dyslexia.[41] Diagnostic assessment on the other hand, is an in-depth assessment designed to identify dyslexia and the pattern of individual strengths and weaknesses.[41] The diagnosis of dyslexia is typically in the domain of education and psychology.[12,42] Psychologists conduct psychometric assessments which include evaluation of cognitive, reading and orthographic skill, and phonological awareness.[12,42]

Neuro-Imaging Techniques Used in the Diagnosis and Study of Dyslexia

Neuro-imaging techniques used in the study of dyslexia can be classified under two broad categories, namely: the structural and functional imaging techniques. The structural imaging techniques include magnetic resonance imaging (MRI) and computed tomography (CT). These techniques are used to provide images of organ anatomy such as the brain shape and size.[43] The functional imaging techniques include positron emission tomography (PET), functional magnetic resonance imaging (fMRI), regional cerebral blood flow (rCBF), magnetoencephalography (MEG) and single photon emission computed tomography (SPECT).[43,44] These functional imaging techniques allow researchers to visualize and map the specific parts of the brain as the individual performs a specific cognitive task such as reading[43-45] and identifies any atypical brain activity in specific areas. Since earlier studies of dyslexia were based on histo-pathological studies, the fMRI has an added advantage that cortical anatomy of the dyslexic brain can be demonstrated in vivo which then addresses the demerits associated with postmortem specimens.[7,43]

Neural Pathways Involved in Reading

In brief, the neural processes involved in reading commences when the textual image seen by the eyes is imaged onto both maculae, and transmitted to both cerebral cortex. Here, it is first received in the primary visual cortex (Brodmann's area 17) where some analysis of the word form takes place. Information from both sides of the occipital lobe is transmitted to the left angular gyrus (area 39). The angular gyrus is central to reading since it is here that hearing, speech and vision meet, and the written word is perceived in its auditory form, (the translation of written language into its speech sound equivalent). The auditory form of the word is then processed for comprehension in Wernicke's area as if the word had been heard.[39]

Aetiology

The leading theory on the aetiology of dyslexia is that dyslexia is a neurological disorder with a genetic origin.[35,46-48] Although the underlying cause of dyslexia is neurological, the exact site of the abnormality remains the subject of on-going research. The aetiological considerations in dyslexia include:

Neurological Factors

Earlier information on the neurobiology of dyslexia was derived from autopsy studies reported by Galaburda *et al.*[49] Four neuro-anatomical distinguishing structures found in dyslexic individual will be discussed. Firstly, it was documented that dyslexic persons do not have asymmetry of the planum temporale that was evident in individuals without dyslexia. The planum temporale is a speech and language area of the brain located in the Sylvian fissure.[2,13,39] As reading is a language-related task, the anatomical differences in one of the language centres of the brain therefore was reported to be consistent with the functional deficits of dyslexia.[39,43] Another perspective is that the dense distributions of ectopias (misplaced neural elements) all over the cerebral cortex (particularly in the perisylvian language areas) resulted in alteration of brain organisation.[39,50] These ectopias reflect the failure of neurons to reach their normal targets during fetal development.[39,50] Furthermore, the slower development of the nerve fibres of the corpus collosum (bundle of cells connecting the left and right hemispheres of the brain) in the dyslexics has also been speculated to be linked to the neurological aetiology of dyslexia. A delay in the growth of corpus collosum would lead to the inadequate development of the language functions.[7] In addition, the lateralization of language functions to the left hemisphere was delayed in dysexics, which subsequently affects the normal development of language areas of the brain.[4,7]

Genetic Factors

A person's ability to acquire reading skills is influenced by their genetic make-up,[37] and a discovery of the underlying genes can help explain the basic neurological pathways that are involved which will ultimately lead to a better understanding of the disorder.[37,51] Dyslexia is a heritable disorder and family history is an important risk factor, with 23-65% of children with family history of dyslexic also found to be dyslexic.[5] However, it is speculated that different forms of dyslexia may occur within the same family, which also may imply that the inheritance may be indirect.[17] Dyslexia is often inherited, but it may also exist in the absence of a family history.[52] Genetic markers have been identified[17,35] in chromosome 18 and chromosomes 6 and 15. Chromosomes 2 (DYX3), 6 (DYX2) and 15 (DYX1) in dyslexics have been reported to be inherited in an autosomal dominant mode of transmission (only one parent has to transmit the gene for expression).[17,35]

Exogenous/Environmental factors

Dyslexia is a neuro-developmental disorder with a genetic basis and environmental factors are risk factors in the manifestation of reading problems,[3,25] Exogenous factors which have been documented to be implicated in the aetiology of dyslexia include:

(i) Peri-natal factors

Various events that disrupt normal cortical growth subsequently affect cognitive and behavioural development of a child.[43] Peri-natal factors may manifest as problems during pregnancy or complications after delivery. Furthermore, the mother's immune system may react to the foetus and attacks it, as if it was an infection. It has also been proposed that dyslexia may occur more often in families who suffered from various autoimmune diseases (such as rheumatoid arthritis, Graves' diseases, multiple sclerosis, systemic lupus and Sjogren's syndrome.)[2,3,7,43]

(ii) Substance use during pregnancy

Toxic agents are known to damage the developing brain by interfering with those processes undergoing development at the time of the exposure.[43] Drugs such

as cocaine (especially in its smokable form known as crack) have been reported to impair fetal growth and cause damage to the central nervous system.[53] Furthermore, mothers who abuse substance during pregnancy are prone to having smaller babies and such infants are predisposed to a variety of problems including learning disorders.[43] Thirdly, alcohol use during pregnancy may influence the child's development and lead to problems with learning, attention, memory or problem solving. There is also a risk of foetal alcohol syndrome (characterised by low birth weight, intellectual impairment, hyperactivity, and certain physical defects).[43]

(iii) Nutrition

Nutrition plays an important role in bridging the gap between genetic constitution and a child's potential for optimal development. Nutrition is a basic requirement for the maintenance of growth and overall development while malnutrition and under-nutrition are associated with disorders in the normal development of intelligence, perceptual maturation, and academic achievements.[43,53]

Theories of dyslexia

The leading assumption of the aetiology of dyslexia remains that dyslexia is caused by subtle abnormalities in the brain. Frith[9] noted that any abnormality at the neurological level in a specific brain system would be expected to affect the mental processes subserved by this system. Consequently, several theories have been proposed to explain the cognitive and behavioural manifestations of dyslexia. These theories may be described as secondary causes of dyslexia and can be classified under four major frameworks: phonological, visual, cerebellar and auditory (although methods of labelling may differ). Each of these theories appears to be different but sometimes overlaps.

The *phonological theory* proposes that the reading difficulties in dyslexia are due to problems in fragment spoken words down into their constituent sound unit (or phonemes), and affected individuals are unable to develop the association between letters (grapheme) and sound (phoneme), a function, which has been considered a major cause of reading and spelling impairment in most cases of developmental dyslexia.[1,15,37] Since most dyslexics show deficits in phoneme processing, the phonological deficit is the most significant, consistent marker of dyslexia and remains the predominant theory[7,29,48] hence the focus on phonology in the majority of remedial programmes.[54] Based on the phonological deficit theory, the other symptoms of dyslexia are considered related factors that may not have a causal relationship with reading disability.[15,48,55]

The *cerebellar theory* (also referred to as the automaticity theory) is related to the role of the cerebellum in automatisation of cognitive processes, motor control (including eye movements) and in speech articulation. Cerebellar dysfunction may cause the impairments in reading and writing characteristic of dyslexia.[27,56-57]

The *visual deficit* (also known as magnocellular) theory suggests that reading difficulties are caused by dysfunction in the neuroanatomy and neurophysiology of the magnocellular subsystem.[18,27] The biological basis of the proposed visual theory relates to the division of the visual system into two sub-systems that carry information to the visual cortex. The two subsystems are the magnocellular (transient) and the parvocellular (sustained) systems.[18,27] The transient system is vital to the timing of visual stimuli and plays an important role in motion perception and ultimately their signals are used to control eye and limb movements made in relation to visual targets.[4,58] Impaired function of magnocellular pathway may lead to destabilization of binocular fixation, resulting in visual confusion and mis-sequencing of letters in a word.[4,58]

The *auditory* (does not refer to peripheral hearing impairment but implies an inability to discriminate between speech sounds) processing theory proposes that there is a deficit in the neural systems responsible for the processing of rapidly presented auditory stimuli. The auditory processing deficit affect the development of the ability to detect and process the dynamic acoustic patterns of speech, leading to impaired phonological processing with a resultant difficulty in reading.[59-60]

The phonological model and learning to read

A consideration of the process of how children learn to read and why reading is much more difficult than speaking will enhance an understanding of reading difficulty in dyslexia. The phonological model is fundamental in the discussion of dyslexia as it reflects a deficiency within a specific component of the language system, which is engaged in processing the sound of words.[1,15] The phonological deficit is

domain-specific, that is, it is independent of other non-phonologic abilities (especially the higher-order cognitive and linguistics functions) such as intelligence and reasoning.[1,15] Unlike learning to speak (which occurs automatically at a preconscious level), learning to read is not a natural biological process. Children do not automatically learn to read, they must be taught. For some children, the ability to break word into its smaller parts (phonemes), a task crucial in reading, is difficult.[1,15]

Phonemes are the smallest units of speech sound that can be uttered in a given language and that can be recognized as being distinct from other sounds in the language.[15,17,37] In order to transform the printed letters on the page to words that have meaning, the letters must be connected to something that already has inherent meaning, which, in this case, is the sound of spoken word.[15,17,37] The child has to rely on the existing brain functioning areas naturally designed to efficiently process spoken language. Reading acquisition builds on the child's spoken language, which is already well developed before the start of formal schooling.[15,17,37] Once a written word is decoded phonologically, its meaning will become accessible via the existing phonology-to-semantics (meaning of words and phrases) link in the oral language system.[15,17,37] A crucial part of this intuitive process is the rapid, automatic and an accurate matching of the component speech sound (phonemes) with their corresponding written representations (graphemes). Thus, the child's awareness of the phonological structure of sound of speech (phonemic awareness) plays a major role in the development of reading ability.[1,2,15,17,37,61] Subsequently, in order to learn to read, children must learn how to link the printed letters on the page to the sounds of spoken language and understand that spoken words are made up of sounds and that letters represent these sounds, or phonemes.[1,2,15,17,37,61] Learning to read requires that the central principle behind the alphabet is understood, that is, speech sounds are made of phonemes and, in print, phonemes are represented by letters. For example, the word "mat" comprises three phonemes "m" "aaaa" "t" but the listener hears this as the holistic word "mat," not as three separate sounds. When we speak, we blend the sounds together and say them as one "mat". To read, a child must learn that there are three separate sounds. This is difficult for children with dyslexia. The inability to break word into its parts is the main reason why children with dyslexia have trouble learning to read.[1,2,15]

Remarkably, the difficulty dyslexics experience is specifically related to the sounds, and not the meaning, of spoken language.[1,2,15] Dyslexic children find it difficult to bring the print to language (such as when asked to read what they just wrote). For example, a child can copy the letters "w-a-s" correctly, but when asked what was written, a child with dyslexia may reply "saw". The problem in this case may not be related to vision, but rather one of perceptual skills of what the child does with a word on a page. The brain mechanism of going from print to language is phonologically based.[1,15,17,37,61] It is important to note that although phonemic awareness is important in learning to read, it needs to be supplemented by a knowledge of letters and of the sounds they represent.[62]

Classifications

Dyslexia can be classified into two broad categories according to its presumed aetiology. According to Helveston[63] dyslexia may be classified as primary and secondary dyslexia. Primary dyslexia (specific developmental dyslexia) is considered to be caused by a specific central nervous system defect specifically located in the angular gyrus. Dyslexia is often hereditary and the decoding process involved in language system is affected and reading becomes extremely difficult for the child.[63] Secondary dyslexia on the other hand results from pathological changes in the central nervous system secondary to trauma or disease, such as childhood meningitis.[63]

Sub-types of dyslexia

Efforts to classify dyslexia into subtypes is difficult because dyslexia is heterogeneous[12] which results in inconsistencies in labeling. Therefore, dyslexia has been subclassified in different ways such as dysphonetic, dyseidetic or dysnemkinesia[8] auditory (aud-linguistic) or visual (visuo-spatial) phonological, deep or surface.[64]

Management and Intervention

The initial approach to the management of the dyslexic child is remediation of reading, often with an emphasis on increasing phonologic awareness.[65] This is followed by providing accommodation as the child enters the more time-demanding setting of secondary school.[29,65] These accommodations include extra time for reading, tape recorders in the classroom, audio books, instruction in word processing and the use

of a spell-checker (poor phonemic association also causes problems in spelling). Overall, intervention for dyslexia lies mainly in the domain of education and psychology.[29,65] However, other professions such as medicine, neuroscience, speech-language therapist, occupational therapist and optometrist play some important roles.[29]

Role of optometry in the multidisciplinary management of dyslexia

Dyslexia is not caused by anomalies of vision and optometrists do not treat dyslexia; they treat visual dysfunction that may impair the ability of a dyslexic child to respond to specific instructions intended to remedy the disability.[66] The primary role of optometry in the multidisciplinary management of dyslexia therefore is to conduct full eye examination and offer appropriate compensation for any vision anomalies, which will improve reading efficiency and then make educational intervention easy.[66-67] The main areas of focus include case history, evaluation of refractive and binocular functions as well as visual information processing.

A detailed case history is essential for children who present with reading dysfunction. A thorough investigation of the pre-natal, peri-natal, and post-natal risk factors is important to establish the possibility of major developmental delay. For example, maternal history of alcoholism may indicate foetal alcohol syndrome. Prematurity (early birth date of less than 37 weeks or low birth weight of less than 2500g) is also a factor in later learning difficulties.[67]A thorough investigation and compensation for refractive and binocular vision functions should be undertaken.[67-68]

For visual information processing deficits, appropriate evaluation and therapy for visual-motor skills, visual-spatial analysis, short-term (visual-motor recall), and auditory analysis skills is recommended. Also, screening for auditory-perceptual skills at the primary care level is essential as the ability to analyze spoken language into separate sounds and sound sequence is directly related to reading and spelling success. Examples of tests to measure auditory perceptual skills are the Test of Auditory Analysis Skills (TAAS) and a more complex one: Test for Auditory-Perceptual Skills.[67]

Optometric treatment options

The optometric treatment options in dyslexia management include correction of vision defects and the use of tinted lenses and coloured overlays.[67-68] Strategies for the correction of vision defects include: compensation for refractive error and binocular vision anomalies with lenses, prisms and vision therapy and treatment of vision information processing deficits with vision therapy commencing with visual spatial orientation, then visual analysis, and concluding with visual-motor integration.[67]

Coloured overlays or coloured filters are sheets of transparent plastic that are placed on the reading material. Meares and Irlen in the 1980s claimed that 'Scotopic sensitivity syndrome' (now called Meares-Irlen syndrome), a syndrome characterized by symptoms such as eye strains, and distortion, light sensitivity, headaches, blurring of print, loss of place, and watery eyes can be alleviated by individually prescribed coloured filters. Coloured overlays were reported to improve reading ability and visual perception and increase sustained reading time. Meares-Irlen syndrome is reported both by people who experience frequent severe headaches of the migraine type, dyslexics as well as good readers.[68-70]

Conclusion

Although there are often inconsistencies in findings in some aspects of the studies on dyslexia, previous and on-going studies offer useful insights and a basis for future studies. Sometimes, contradictory findings associated with dyslexia may indeed indicate that multiple causes interact in complex ways to impair reading acquisition in developmental dyslexia.[9] In fact, modern imaging techniques have given tremendous boost to dyslexia research. Therefore, our understanding of dyslexia is an ongoing process and further multidisciplinary researches will continue to enhance our understanding of all aspects of the concept of dyslexia. Dyslexia has a negative impact on a child's education and on the society. If ignored, dyslexic children may end up as dropouts and delinquents due to frustration from difficulty with reading. Hence, bringing together independent studies on dyslexia will contribute to a better understanding, earlier detection and possible intervention. Optometry has a major role in attending to visual problems which may interfere with educational interventions and an understanding of the basic concept of dyslexia will be beneficial.

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Note: URLs and underlined text are functional hyperlinks to Internet addresses.

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