Perspectives on dyslexia

Linda S Siegel PhD

LS Siegel. Perspectives on dyslexia. Paediatr Child Health 2006;11(9):581-587.

Dyslexia, or a reading disability, occurs when an individual has significant difficulty with speed and accuracy of word decoding. Comprehension of text and spelling are also affected. The diagnosis of dyslexia involves the use of reading tests, but the continuum of reading performance means that any cutoff point is arbitrary. The IQ score does not play a role in the diagnosis of dyslexia. The cognitive difficulties of dyslexics include problems with speech perception, recognizing and manipulating the basic sounds in a language, language memory, and learning the sounds of letters. Dyslexia is a neurological condition with a genetic basis. There are abnormalities in the brains of dyslexic individuals. There are also differences in the electrophysiological and structural characteristics of the brains of dyslexics. Physicians play a particularly important role in recognizing children who are at risk for dyslexia and helping their parents obtain the proper assessment.

Key Words: *Dyslexia; Learning disabilities; Reading disability*

Des perspectives sur la dyslexie

La dyslexie, une déficience de lecture, se produit lorsque l'individu éprouve d'énormes difficultés dans la vitesse et l'exactitude du décodage des mots. La compréhension de texte et l'épellation sont également touchées. Pour poser un diagnostic de dyslexie, il faut utiliser des tests de lecture, mais en raison de la séquence d'exécution de la lecture, toute limite d'inclusion est arbitraire. Le QI n'a rien à voir dans le diagnostic de dyslexie. Les troubles cognitifs des dyslexiques comprennent des troubles de perception du langage, de reconnaissance et de manipulation des sons fondamentaux d'une langue, de mémoire de la langue et d'apprentissage du son des lettres. La dyslexie est un trouble neurologique aux fondements génétiques. On remarque des anomalies dans le cerveau des dyslexiques, de même que des différences dans les caractéristiques électrophysiologiques et structurelles de leur cerveau. Les médecins jouent un rôle particulièrement important dans le dépistage des enfants vulnérables à la dyslexie et dans l'aide aux parents afin qu'ils obtiennent une évaluation convenable.

Dyslexia, also known as a reading disability, occurs when an individual has significant difficulty with speed and accuracy of word decoding. Comprehension of text is also affected. Dyslexia is usually accompanied by spelling difficulties. Dyslexia is stable, in that children identified as dyslexic are likely to continue to have reading difficulties throughout adolescence and adulthood (1,2).

DEFINITIONAL ISSUES

There are many complex issues to consider in developing an appropriate definition of dyslexia. One of the major problems is that there is no specific blood test or brain imaging result that can provide a diagnosis. Fundamentally, the issue is that reading is measured on a continuum and there is no cutoff score on a reading test that clearly divides individuals into dyslexic and nondyslexic groups. The distinction between dyslexia and normal reading is arbitrary; where the cutoff point is drawn varies from study to study.

Ellis (3) invokes a medical analogy when discussing dyslexia: "First, reading backwardness seems to be a graded thing more like obesity than measles. We cannot in any simple way divide the population into those who are dyslexic and those who are not, so it would seem unlikely that there will exist any symptom or sign that will quantitatively distinguish dyslexics from nondyslexics".

In discussing the arbitrary nature of dyslexia, Shaywitz et al (4) noted: "Our findings indicate that dyslexia is not an all-or-nothing phenomenon, but like hypertension and obesity, occurs in varying degrees of severity. Although limitations on resources may necessitate the imposition of cutoff points for the provision of services, physicians must recognize that such cutoffs may have no biological validity".

Exactly where the line is between dyslexic and nondyslexic is subjective and controversial. This relative uncertainty does not dispute the reality of dyslexia, but instead indicates that there is some subjectivity in the diagnosis.

Operationalizing the definition of dyslexia has proved to be contentious and difficult. First, there is the question of which reading test to use. It is now considered important to use a test of single isolated word reading, such as the Woodcock-Johnson Word Identification subtest or the Wide Range Achievement Test. In both of these tests, the individual is required to read words that increase in difficulty (eg, from simple words to complex multisyllable words, such as 'cat', 'emphasis' and 'idiosyncrasy'). Test scores are compared with scores from other individuals of the same age level.

An important test for dyslexia is a test of pseudoword reading (eg, the Woodcock Word Attack test). This test involves the reading of pronounceable combinations of

University of British Columbia, Vancouver, British Columbia
Correspondence: Dr Linda S Siegel, ECPS, 2125 Main Mall, University of British Columbia, Vancouver, British Columbia V6T 1Z4. Telephone 604-822-0052, fax 604-822-3302, e-mail linda.siegel@ubc.ca

letters that do not represent English words but can be articulated using the pronunciation rules of English. Examples include items such as 'bab', 'shum', 'cigbet' and 'bafmotbem'. This is a test of basic decoding skills. Having these decoding skills is especially important when learning to read and to be able to ascertain the pronunciation of new words that have never been encountered before.

The discrepancy definition

Until recently, the typical definition of dyslexia involved a discrepancy between an IQ score and a reading score. If the IQ score was found to be significantly higher than the reading score, then this discrepancy was used as an index of dyslexia. This definition has been discredited for a variety of reasons. A detailed discussion on this topic can be found elsewhere (5). The IQ test measures vocabulary, verbal memory and specific knowledge, and these are skills that may be deficient in the dyslexic. Therefore, the IQ score may be an inadequate measure of the so-called intellectual potential of a dyslexic. In addition, a number of studies (6-9) in different countries have found that there are no differences in children who have reading problems between those who have a discrepancy between IQ and reading scores and those who do not. These findings suggest that a discrepancy between IQ and reading scores is not necessary to indicate dyslexia, and that a low score on a reading test is, in fact, an indication of a reading problem. There is evidence to suggest that a child's IQ score does not predict his or her ability to benefit from remediation (10,11).

Another issue is which cutoff score to use to diagnose dyslexia. Basically, reading scores are a continuous distribution. At some point in the reading, the delay becomes so severe (compared with other individuals of the same age and educational background) that we call it dyslexia.

Although reading comprehension is important and is the major purpose for reading, dyslexia is best recognized by difficulties at the word level. Decoding words is critical for developing comprehension skills. Reading comprehension is usually tested by having the individual read a passage and answer questions about the passage. Reading comprehension tests are usually timed. There are some individuals who, although they can read words, have difficulty with reading comprehension because they may lack the inferential skills to make sense of what they read, or because they may read slowly. They may not have sufficient background knowledge to understand the text or the questions. Lesaux et al (12) found that giving dyslexics extra time on a reading comprehension test improved their reading scores.

PREVALENCE

Estimates of prevalence depend on the particular definition of dyslexia used in the study (13,14). Depending on the definition used, 5% to 10% of the population is considered to have dyslexia; however, because of the nature of the definitional issues (as described above), an estimate of prevalence is specific to a particular sample and to the definition used in a study.

HISTORY

Dyslexia was first described in the scientific literature by several physicians, who noted cases of individuals with apparently normal intelligence who could not learn to read (15). These cases were called word blindness. One of the pioneers in the field of dyslexia was Orton (16), who believed that the problem in dyslexia was one of visual perception and visual memory.

In the years that followed, various theories, including hypotheses about motor difficulties and perceptual problems as the basis of dyslexia, were advanced. The belief was that dyslexia was a perceptual problem, stemming from the idea of word blindness. It was also a common belief, and probably a belief held by many today, that the defining symptom for dyslexia was writing letters and words backwards. This conceptualization of dyslexia as a visual problem and as the primary symptom being the writing of letters and words backwards has been discredited by studies, including those by Liberman et al (17) and Vellutino (18).

TWO ROUTES TO READING

Scientists have used theories about reading to help understand dyslexia. One of the most widely accepted theories of reading is called the dual route theory (19). In this theory, there are two mechanisms that individuals use to read words: the direct (orthographic) route and the indirect (phonological) route. The direct route involves looking at a word and automatically knowing what it says. For frequently used words and words that have been seen before, this route is probably the one that is used. Skilled readers use this route for most of what they read, although they can use another route when they encounter words that are either new or relatively unfamiliar. The indirect route involves translating the letters into sounds and knowing the pronunciation of words from the combination of sounds. The use of this route involves what is called phonological processing. This route is commonly used at the beginning of the development of reading skills in which words are carefully sounded out and in more advanced readers when they encounter new words. Most dyslexics have a great deal of difficulty with this route because they lack phonological skills.

COGNITIVE ASPECTS OF DYSLEXIA

A breakthrough in the understanding of dyslexia occurred approximately 35 years ago, when a picture of the major cognitive difficulties in dyslexia began to emerge more clearly (20). Liberman and colleagues (20-22) recognized the importance of speech and language as the basis for reading, and that children must map the written word on to the spoken word when learning to read. It was assumed in the past that visual difficulties or problems with hand-eye coordination served as the basis for dyslexia. It is now clear that the major problem with dyslexia involves difficulties with phonological processing, that is, being able to segment words into their component sounds, and associate letters with their sounds and phonological awareness (ie, the ability to segment speech into small parts, such as syllables, and the

smallest units of sound, phonemes). As young children, dyslexics have difficulties with tasks such as discriminating the individual sounds in words (eg, what does 'pink' with out the 'p' say?), recognizing words that rhyme (eg, which of the following words rhymes with cat: sun, hat or star) or recognizing whether 'cat' and 'kite' start with the same sound (20,23). Studies such as those by Lundberg et al (24) and Elbro and Petersen (25) have shown that children who receive training in these phonological awareness skills demonstrate improved reading abilities.

One aspect of this phonological deficit is that dyslexics show subtle difficulties in speech perception at the level of the phoneme. Studies such as those by Godfrey et al (26), Manis et al (27), Reed (28) and Werker and Tees (29) have shown that dyslexics perform poorer than nondyslexics on measures of speech perception. For example, Bertucci et al (30) found that the perception and production of vowels were particularly difficult for dyslexics. The speech processing difficulties for dyslexics include weak phonological coding for vowel sounds with similar phonetic characteristics.

Mody et al (31) found differences between some dyslexics and nondyslexics with respect to the discrimination of sounds such as 'ba' and 'da'. Only some dyslexics have this problem. As methods of speech and sound science advance, it may eventually be found that this speech perception problem is one of the fundamental difficulties of the dyslexic.

When dyslexics are learning to read, they have trouble learning the sounds of letters and the spelling of words. Later on, although they can read words, their reading may be slow, and many have difficulty remembering what they have read. Stanovich (32) provided evidence for what he called the 'Matthew effect' (based on the writings of Matthew in the Bible that the rich get richer and the poor get poorer). Stanovich (32) states that "individuals who have advantageous early educational experiences are able to utilize new educational experiences more efficiently". In contrast, children who have reading difficulties read less and do not acquire the vocabulary and concepts that they need and, thus, fall further behind in their reading and academic skills.

GENETIC AND NEUROLOGICAL BASIS

Dyslexia has a genetic basis, and it is clear that dyslexia tends to run in families (Table 1). Research has identified several chromosomes that appear to contain the gene or genes for dyslexia, although the exact genetic mechanisms and the inheritance patterns are not known. Familial studies (33-39) and discoveries regarding the involvement of specific chromosomes (40-42) clearly indicate the genetic basis of dyslexia. Chromosomes 6 and 15 have been implicated. Obviously, environmental factors play a role, but the role of genetics is quite strong (43). A study by Castles et al (43) found that phonological dyslexia (in which individuals have more trouble reading pseudowords) was more heritable than orthographic dyslexia (in which individuals have more trouble reading exception words), although both types showed a significant heritability.

TABLE 1
Risk factors for dyslexia

Family history
Early speech delay
Prematurity
Very low birth weight (<1500 g)

There is clearly a neurological basis for dyslexia. A number of postmortem studies have indicated abnormalities in the brains of dyslexic individuals (44,45). The universal finding is an absence of the usual asymmetry in the planum temporale. There may also be structural differences between dyslexics and nondyslexics in the corpus callosum, which controls the communication between the two hemispheres of the brain (46,47).

A number of electrophysiological studies have shown differences between dyslexics and nondyslexics. Event-related potentials may be used to measure the timing and the brain areas used during the cognitive processing of print and language. For example, a number of studies (48-50) have found that the event-related potentials of dyslexics, in contrast with nondyslexics, failed to show what is called mismatched negativity, which is a negative deflection in the wave in response to a change in the stimulus.

Functional magnetic resonance imaging has shown that there are structural differences in the brains of dyslexics and nondyslexics. The exact nature of these differences varies from study to study. In general, differences in the planum temporale have been found such that asymmetries are great in the nondyslexic, and the direction may even be reversed in the dyslexic (51,52). Casanova et al (53) found abnormalities in the left hemisphere of dyslexic individuals; specifically, the following structures were involved: extrapyramidal and limbic systems, amygdala, hippocampus, parahippocampal gyrus, putamen and globus pallidus.

SEX

Although it is a common belief that men are significantly more likely to be dyslexic than women, this assumed sex imbalance is not substantiated by recent research (54,55). There may be slightly more men than women who have dyslexia, but the difference is not significant. This notion is illustrated by a study (56) of an epidemiological sample of children in grades 2 and 3 in which reading and IQ tests were used to provide a psychometric definition of dyslexia. The investigators found that 8.7% of the boys and 6.9% of the girls were dyslexic in grade 2, and that 9.0% of the boys and 6.0% of the girls were dyslexic in grade 3. However, when they examined the sex differences in referral rates in the dyslexics identified by the teachers, they found that 13.6% of the boys and 3.2% of the girls were identified as dyslexic in the second grade, and that 10.0% of the boys and 4.2% girls were identified as dyslexic in the third grade, indicating a significant referral bias in favour of boys. Although the actual incidence of dyslexia was similar in

boys and girls, boys were much more likely to be referred for possible assessment. In general, Shaywitz et al (56) found that the boys were identified because of behavioural difficulties in the classroom, which drew the teacher's attention to them. The girls were much less likely to have behaviour problems and, thus, were not identified as having reading difficulties, although they were almost as likely as boys to have a disability.

ASSESSMENT OF DYSLEXIA

Any individual (child or adult) in whom a reading problem is suspected should receive an assessment. This assessment is available in schools and in institutions of higher education. The assessment should involve a thorough measurement of reading, spelling and arithmetic skills. An intelligence test or IQ score is not necessary, as demonstrated by the latest research in the area; however, despite the literature, some jurisdictions still require an IQ test. This state of affairs is unfortunate because there is either a long wait time for testing – sometimes as long as one to two years in many school districts – or parents or individuals must go to a private psychologist to receive the testing, which is quite expensive and out of the financial reach of many individuals. However, third party insurers may cover the cost in some instances.

CROSS-LINGUISTIC STUDIES

Dyslexia has the same manifestation in all alphabetic languages that have been studied and in languages that are nonalphabetical, such as Chinese and Japanese. The primary deficit is phonological (even in Chinese), although problems with visual memory, short-term verbal memory and syntax exist in dyslexia in all languages (57).

EDUCATIONAL INTERVENTIONS

There are a number of educational interventions that can be useful in helping the dyslexic individual. Some of these are direct treatments, while others involve providing accommodations to the learning environment.

Accommodations

Educational accommodations include the use of computers, tape recorders, screen readers and speech recognition devices. Many dyslexics have illegible handwriting. The computer can be especially useful, particularly if touch typing skills are learned. Computers also have spell checking programs, which are particularly useful because dyslexics have poor spelling. Tape recorders can be useful for the child to record his or her ideas, which can then be transcribed later. Tape recorders can also be useful in classes and lectures because note taking skills can be a problem for dyslexic individuals. Screen readers are devices that read aloud what is on the computer screen and can be very helpful for dyslexics. Books on tape can also be helpful. Speech recognition devices and programs are especially useful; the individual can talk into a microphone and see his or her words appear on the screen.

Treatment

In some cases of dyslexia, the direct and systematic teaching of letters and their corresponding sounds (ie, phonological skills) is an important way to help dyslexics. Programs such as those described by Hatcher (58) and Nicolson et al (59) systematically teach individuals the sounds of the letters and have been found to be successful.

Vaughn et al (60) found that programs designed to enhance reading fluency or reading strategies resulted in improved reading for children with reading difficulties.

Lovett et al (61-64) and Vellutino and Scanlon (65) used a detailed program that involved training in word recognition and decoding skills to improve the reading skills of dyslexic children.

Computerized programs have been helpful in some cases. In one study, Wise et al (66) used computers to help dyslexic children. Children read books on computers that were linked to speech synthesizers and then obtained feedback on words that were difficult for them. As a result of this system, the children's attitudes toward reading improved. Irausquin et al (67) showed that computerized exercises that train speed or automatization are helpful in improving the reading of dyslexic individuals. Lovett et al (68,69) used a computer speech-based program to train reading skills in dyslexic children.

It is also important to discover the talents of dyslexics. Many dyslexics are gifted in sports, art, music or dance (70), while others have superior visuospatial skills. These skills can be useful in careers such as architecture or engineering.

COMORBIDITY

Dyslexia frequently occurs with other conditions, such as an arithmetic learning disability, attention deficit disorder, attention deficit hyperactivity disorder, obsessive-compulsive disorder and Tourette's syndrome (71). Reading and language disorders may be associated with behavioural difficulties, but it is likely in many cases that the behavioural difficulties are a consequence of the reading difficulty and not a cause of it (72). It is particularly important that physicians do not ignore the possibility of dyslexia when other developmental disorders are present.

IMMIGRANT CHILDREN AND DYSLEXIA

Canada is a multicultural, multiethnic nation. Especially in the larger cities, there are significant numbers of children who are being educated in school in a language other than their native tongue. There has been some research conducted on children learning English as a second language, but very little research on immigrant children learning French as a second language. In general, these studies found that if immigrant children enter school in the first few grades and receive good instruction, they can catch up to their nonimmigrant peers (73,74). What is important to know is that children who are still having significant difficulties after a few months or a year of

instruction in English may be dyslexic. Often, these children are ignored and the problem is assumed to be due to the fact that their first language is not English. In reality, children who struggle in school, even if their first language is not English, should be screened and assessed to determine whether they are dyslexic. Considering the significant dropout rate of children whose first language is not English, it is very important to investigate the possibility of dyslexia.

DYSLEXIA AND PREMATURITY

Very low birth weight children, that is, children whose birth weights are lower than 1500 g, are at significant risk for dyslexia and other learning disorders (8,75,76) (Table 1). Unfortunately, these children are less likely to be identified because their difficulties are less likely to be recognized.

SIGNS OF DYSLEXIA

Delayed language development may indicate that a child is at risk for dyslexia. Children who show delayed language development at three and four years of age are at risk for dyslexia, although many children who eventually become dyslexic have perfectly normal language development. Studies (77,78) have shown that early language difficulties and a diagnosis of language impairment in childhood is predictive of reading disabilities in the later school years and during adolescence and adulthood. Although not all children who have language disorders in early childhood become dyslexic, it is a very important indicator of a possible problem; these children should be monitored very carefully.

Academic difficulties in school, especially difficulty with learning how to read, are a sign of dyslexia. Although children learn to read at different rates, if a child is having difficulty and performing significantly below his or her peers after a few months of reading instruction, this delay is a sign of a potential problem and should not be ignored.

School phobia and/or somatic complaints that appear on school days, especially on Monday, are a sign of a possible learning disability (Table 2). Prompt treatment and investigation of a possible reading problem or other learning difficulty is critical.

PREVENTION

Children at risk for reading difficulties can be identified in kindergarten (five years of age) and intervention programs can be provided. In one study, Lesaux and Siegel (74) found that children identified as at-risk for reading difficulties in kindergarten, regardless of whether their first language was English, benefited from classroom-based intervention programs that emphasized phonological awareness, vocabulary and reading strategies.

CURRENT DIRECTIONS IN DYSLEXIA

Recently, an alternative to the labelling of individuals as dyslexic to make them eligible for special education services has been proposed. The model is called Response to Instruction and it involves the early identification of children with difficulties, providing a classroom based-intervention and then providing more individualized academic intervention for children who still continue to have difficulties. This model holds promise for the prevention, or at the very least the reduction, of serious reading problems. It is considerably less costly than a model that requires extensive testing and waiting until the child is failing before help is considered.

TABLE 2
Signs of dyslexia

Difficulty learning to read
Somatic complaints
School phobia

TABLE 3
Screening tools

Standardized tests of the following areas can be used for screening:
• Word reading
• Pseudoword reading
• Reading comprehension
• Spelling
• Arithmetic

CONCLUSIONS

It is important to recognize that behavioural difficulties in school may be a sign of dyslexia. Any sign of problems in learning to read, even very early in a child's school career, should be taken seriously and investigated. The common assumption that the child will grow out of the problem is not a valid one in most cases. We know that early identification and early intervention can prevent most serious reading difficulties, or at least reduce the severity of them. Any school difficulties or behavioural problems should be investigated immediately. School phobia and/or somatic complaints that appear on school days are a sign of a possible learning disability.

Physicians have an important role to play in the identification of children at risk for dyslexia. In addition to recognizing the signs of possible dyslexia, physicians or their office staff may be able to conduct some brief screening tests, including some standardized tests of reading, spelling and arithmetic (Table 3).

There is evidence that significant numbers of dyslexics are represented in populations of runaway homeless street youths (79), adolescent suicide victims (80) and juvenile offenders (81). It is important that we recognize these difficulties early and make an attempt to eliminate them or reduce their severity.

Physicians have a particularly important role in recognizing a child who is at risk for dyslexia and helping the parents obtain the proper assessment.

REFERENCES

1. Bruck M. Word-recognition skills of adults with childhood diagnoses of dyslexia. Dev Psychol 1990;26:439-54.
2. Shaywitz SE, Fletcher JM, Holahan JM, et al. Persistence of dyslexia: The Connecticut Longitudinal Study at adolescence. Pediatrics 1999;104:1351-9.
3. Ellis AW. Reading, writing, and dyslexia: A cognitive analysis. London: Eribaum, 1984.
4. Shaywitz SE, Escobar MD, Shaywitz BA, Fletcher JM, Makuch R. Evidence that dyslexia may represent the lower tail of a normal distribution of reading ability. N Engl J Med 1992;326:145-50.
5. Siegel LS. IQ is irrelevant to the definition of learning disabilities. J Learn Disabil 1989;22:469-78.
6. Fletcher JM, Francis DJ, Rourke BP, Shaywitz SE, Shaywitz BA. The validity of discrepancy-based definitions of reading disabilities. J Learn Disabil 1992;25:555-61.
7. Gustafson S, Samuelsson S. Intelligence and dyslexia: Implications for diagnosis and intervention. Scand J Psychol 1999;40:127-34.
8. Sameulsson S, Bylund B, Cervin T, et al. The prevalence of reading disabilities among very-low-birth-weight children at 9 years of age-dyslexics or poor readers? Dyslexia 1999;5:94-112.
9. Siegel LS. An evaluation of the discrepancy definition of dyslexia. J Learn Disabil 1992;25:618-29.
10. Vellutino FR, Scanlon DM, Sipay ER, et al. Cognitive profiles of difficult-to-remediate and readily remediated poor students: Early intervention as a vehicle for distinguishing between cognitive and experimental deficits as basic causes of specific reading disability. J Educ Psychol 1996;88:601-38.
11. Vellutino FR, Scanlon DM, Lyon GR. Differentiating between difficult-to-remediate and readily remediated poor readers: More evidence against the IQ-achievement discrepancy definition of reading disability. J Learn Disabil 2000;33:233-8.
12. Lesaux NK, Lipka O, Siegel LS. Investigating cognitive and linguistic abilities that influence the reading comprehension skills of children from diverse linguistic backgrounds. Reading and Writing 2006;19:99-131.
13. Rodgers B. The identification and prevalence of specific reading retardation. Br J Educ Psychol 1983;53:369-73.
14. Shaywitz BA, Fletcher JA, Holahan JM, Shaywitz SE. Discrepancy compared to low achievement definitions of reading disability: Results from the Connecticut Longitudinal Study. J Learn Disabil 1992;25:639-48.
15. Morgan WP. A case of congenital word blindness. BMJ 1896;2:1378.
16. Orton ST. Word-blindness in school children. Archives of Neurological Psychiatry 1925;14:197-9.
17. Liberman IY, Shankweiler D, Orlando C, Harris KS, Berti FB. Letter confusions and reversals of sequence in the beginning reader: Implications for Orton's theory of developmental dyslexia. Cortex 1971;7:127-42.
18. Vellutino FR. Dyslexia: Theory and Research. Cambridge: MIT Press, 1979.
19. Coltheart M, Curtis B, Atkins P, Haller M. Models of reading aloud: Dual-route and parallel-distributed-processing approaches. Psychol Rev 1993;100:589-608.
20. Liberman IY. Segmentation of the spoken word and reading acquisition. Bulletin of the Orton Society 1973;23:65-77.
21. Liberman IY, Shankweiler D. Speech, the alphabet, and teaching to read. Theory and Practice of Early Reading. New Jersey: Erlbaum, 1979;2:109-32.
22. Liberman I, Shankweiler D. Phonology and the problem of learning to read and write. Remedial and Special Education 1985;6:8-17.
23. Bradley L, Bryant PE. Categorizing sounds and learning to read: A causal connection. Nature 1983;30:419-21.
24. Lundberg I, Frost J, Peterson OP. Effects of an extensive program for stimulating phonological awareness in preschool children. Reading Research Quarterly 1998;23:263-84.
25. Elbro C, Petersen DK. Long-term effects of phoneme awareness and letter sound training: An intervention study with children at risk for dyslexia. J Educ Psychol 2004;96:660-70.
26. Godfrey JJ, Syrdal-Lasky AK, Millay KK, Knox CM. Performance of dyslexic children on speech perception tests. J Exp Child Psychol 1981;32:401-24.
27. Manis FR, Mcbride-Chang C, Seidenberg MS, et al. Are speech perception deficits associated with developmental dyslexia? J Exp Child Psychol 1997;66:211-35.
28. Reed MA. Speech perception and the discrimination of brief auditory cues in reading disabled children. J Exp Child Psychol 1989;48:270-92.
29. Werker JF, Tees JC. Speech perception in severely disabled and average reading children. Can J Psychol 1987;41:48-61.
30. Bertucci C, Hook P, Haynes C, Macaruso P, Bickley C. Vowel perception and production in adolescents with reading disabilities. Annals of Dyslexia 2003;53:174-200.
31. Mody M, Studdert-Kennesy M, Brady S. Speech perception deficits in poor readers: Auditory processing or phonological coding? J Exp Child Psychol 1997;64:199-231.
32. Stanovich KE. Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. Reading Research Quarterly 1986;21:360-407.
33. Pennington BF. Genetic and neurological influences on reading disability: An overview. Reading and Writing 1991;3:191-201.
34. Pennington BF, Siegel LS. Dimensions of Executive Functions in Normal and Abnormal Development. In: NA Krasnegor, PS Goldman-Rakic, eds. Development of the Prefrontal Cortex: Evolution, Neurobiology, and Behaviour. Baltimore: Paul H Brookes Publishing, 1997:265-281.
35. Pennington B. Toward an integrated understanding of dyslexia: Genetic, neurological and cognitive mechanisms. Dev Psychopathol 1999;11:629-54.
36. Schulte-Korne G, Deimel W, Muller K, Gutenbrunner C, Remschmidt H. Familial aggregation of spelling disability. J Child Psychol Psychiatry 1996;37:817-22.
37. Snowling M, Bishop DV, Stothard SE. Is preschool language impairment a risk factor for dyslexia in adolescence? J Child Psychol Psychiatry 2000;41:587-600.
38. Fisher S, DeFries J. Developmental dyslexia: Genetic dissection of a complex cognitive trait. Nature Reviews. Neuroscience 2002;3:767-80.
39. Regehr SM, Kaplan BJ. Reading disability with motor problems may be an inherited subtype. Pediatrics 1988;82:204-10.
40. Fagerheim T, Raeymaekers P, Tonnessen FE, Pedersen M, Tranebjaerg L, Lubs HA. A new gene (DYX3) for dyslexia is located on chromosome 2. J Med Genet 1999;36:664-9.
41. Fisher SE, Marlow AJ, Lamb J, Maestrini E, Williams DF, Richardson AJ. A quantitative-trait locus on chromosome 6p influences different aspects of developmental dyslexia. Am J Hum Genet 1999;64:146-56.
42. Gayán J, Smith SD, Cherny SS, et al. Quantitative-trait locus for specific language and reading deficits on chromosome 6p. Am J Hum Genet 1999;64:157-64.
43. Castles A, Datta H, Gayan J, Olson RK. Varieties of developmental reading disorder: Genetic and environmental influences. J Exp Child Psychol 1999;72:73-94.
44. Galaburda AM, Kemper TL. Cytoarchitectonic abnormalities in developmental dyslexia: A case study. Ann Neurol 1979;6:94-100.
45. Galaburda AM, Sherman GF, Rosen GD. Developmental dyslexia: Four consecutive patients with cortical anomalies. Ann Neurol 1985;18:222-33.
46. Robichon F, Habib M. Abnormal callosal morphology in male adult dyslexics: Relationships to handedness and phonological abilities. Brain Lang 1998;62:127-46.
47. Robichon F, Bouchard P, Demonet J, Habib M. Developmental dyslexia: Re-evaluation of the corpus callosum in male adults. Eur Neurol 2000;43:233-7.
48. Kraus N, McGee TJ. Auditory neurophysiologic responses and discrimination deficits in children with learning problems. Science 1996;273:971.
49. Kujala T. Basic auditory dysfunction in dyslexia as demonstrated by brain activity measurements. Psychophysiology 2000;37:262-6.
50 Schulte-Korne G, Deimel W, Bartling H. Auditory processing and dyslexia: Evidence for a specific speech processing deficit. Neuroreport 1998;9:337-40.
51. Hynd GW, Semrud-Clikeman M, Lorys AR, Novey ES, Eliopulos D. Brain morphology in developmental dyslexia and attention deficit disorder/hyperactivity. Arch Neurol 1990:47;919-26.

52. Leonard CM, Voeller KK, Lombardino LJ, et al. Anomalous cerebral structure in dyslexia revealed with magnetic resonance imaging. Arch Neurol 1993;50:461-9.
53. Casanova PF, Garcia-Linares MC, De la Torre MJ, De la Villa Carpio M. Influence of family and sociodemographic variables on students with low academic achievement. Educ Psychol 2005;25:423-35.
54. Shaywitz SE, Shaywitz BA, Fletcher JM, Escobar MD. Prevalence of reading disability in boys and girls. Results of the Connecticut Longitudinal Study. JAMA 1990;264:998-1002.
55. Siegel LS, Smythe IS. Reflections on research on reading disability with special attention to gender issues. J Learn Disabil 2005;38:473-7.
56. Shaywitz SE, Escobar MD, Shaywitz BA, Fletcher JM, Makuch R. Distribution and temporal stability of dyslexia in an epidemiological sample of 414 children followed longitudinally. N Engl J Med 1992;326:145-50.
57. Ho CS, Bryant P. Phonological skills are important in learning to read Chinese. Dev Psychol 1997;33:946-51.
58. Hatcher PJ. Reading intervention: a 'conventional' and successful approach to helping dyslexic children acquire literacy. Dyslexia 2003;9:140-5.
59. Nicolson RI, Fawcett AJ, Moss H, Nicolson MK, Reason R. Early reading intervention can be effective and cost-effective. British Journal of Educational Psychology 1999;69:47-62.
60. Vaughn S, Chard DJ, Bryant DP, et al. Fluency and comprehension interventions for third-grade students. Remedial and Special Education 2000;21:325-35.
61. Lovett M, Ransby MJ, Barron RW. Treatment, subtype, and word type effects in dyslexic children's response to remediation. Brain Lang 1988;34:328-49.
62. Lovett MW, Ransby MJ, HardwicK N, Johns MS, Donaldson SA. Can dyslexia be treated? Treatment-specific and generalized treatment effects in dyslexic children's response to remediation. Brain Lang 1989;37:90-121.
63. Lovett M, Benson N, et al. Individual difference predictors of treatment outcome in the remediation of specific reading disability. Learning and Individual Differences 1990;2:287-314.
64. Lovett M, Warren-Chaplin PM, Ransby MJ, Borden SL. Training the word recognition skills of reading disabled children: Treatment and transfer effects. J Educ Psychol 1990;82:769-80.
65. Vellutino FR, Scanlon DM. Phonological coding, phonological awareness, and reading ability: Evidence from a longitudinal and experimental study. Merril-Palmer Quarterly 1987;33:321-63.
66. Wise B, Olson R, Anstett M, et al. Implementing a long-term computerized remedial reading program with synthetic speech feedback: Hardware, software, and real-world issues. Behav Res Meth Instrum Comput 1989;21:173-80.
67. Irausquin R, Drent J, Verhoeven L. Benefits of computer-presented speed training for poor readers. Ann of Dyslexia 2003;55:246-65.
68. Lovett MW, Barron RW, Forbes JE, Cuksts B, Steinbach KA. Computer speech-based training of literacy skills in neurologically impaired children: A controlled evaluation. Brain Lang 1994;47:117-54.
69. Lovett MW, Borden SL, DeLuca T, Lacerenza L, Benson NJ, Brackstone D. Treating the core deficits of developmental dyslexia: Evidence of transfer of learning after phonologically- and strategy-based reading training programs. Dev Psychol 1994;30:805-22.
70. Wolff U, Lundberg I. The prevalence of dyslexia among art students. Dyslexia 2002;8:34-42.
71. Pauc R. Comorbidity of dyslexia, dyspraxia, attention deficit disorder (ADD), attention deficit hyperactive disorder (ADHD), obsessive compulsive disorder (OCD), and tourette's syndrome in children: A prospective epidemiological study. Clinical Chiropractic 2005;8:189-98.
72. Tomblin JB, Buckwalter PR. Studies of genetics of specific language impairment. In: R Watkins, M Rice, eds. Specific Language Impairments in Children. Baltimore: Paul H Brookes, 1994:17-34.
73. Hutchinson JM, Whiteley HE, Smith CD, Connors L. The early identification of dyslexia: Children with English as an additional language. Dyslexia 2004;10:179-95.
74. Lesaux NK, Siegel LS. The development of reading in children who speak English as a second language. Dev Psychol 2003;39:1005-9.
75. Litt J, Taylor HG, Klein N, Hack M. Learning disabilities in children with very low birthweight: Prevalence, neuropsychological correlates, and educational interventions. J Learn Disabil 2005;38:130-41.
76. Siegel LS. Correction for prematurity and its consequences for the assessment of the very low birth weight infant. Child Dev 1983;54:1176-88.
77. Catts HW, Gillispie M, Leonard LB, Kail RB, Miller CA. The role of speed of processing, rapid naming, and phonological awareness in reading achievement. J Learn Disabil 2002;35:510-24.
78. Young AR, Beitchman JH, Johnson C, et al. Young adult academic outcomes in a longitudinal sample of early identified language impaired and control children. J Child Psychol Psychiatry 2002;43:635-45.
79. Barwick M, Siegel LS. Learning difficulties in adolescent clients of a shelter for runaway and homeless street youths. J Res Adolesc 1996;6:649-70.
80. McBride HE, Siegel LS. Learning disabilities and adolescent suicide. J Learn Disabil 1997;30:652-9.
81. Snowling M, Bishop DV, Stothard SE. Is preschool language impairment a risk factor for dyslexia in adolescence? J Child Psychol Psychiatry 2000;41:587-600.