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# Language and learning disorders

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**Abstract**

**Objective:** To aid health professionals, especially pediatricians, in the diagnosis and prevention of language and learning disorders.

**Sources of data:** Review of the relevant literature published in the past 5 years (MEDLINE and textbooks).

**Summary of the findings:** Multiple variables, among them neurological diseases, may be related to the etiology of language and learning disorders.

**Conclusion:** An adequate diagnostic investigation may guide the choice of treatment.

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Most of the problems reported in clinical pediatrics, neurology, neuropsychology and speech therapy are related to learning disabilities and/or developmental language disorders.

Learning disabilities are believed to be closely related to a past history of developmental language disorders. Learning disabilities are concerned with abnormal development of verbal and/or written expression and reception. Therefore, the early detection of these disabilities prevents later educational and social consequences.[1]

The aim of the present study is to provide health professionals, especially pediatricians, with adequate tools, so as to diagnose and prevent oral and written language disorders. To start with, we focus on the normal language developmental process, the neurobiological and environmental causes of these disorders, showing their implication on several developmental stages. Finally, we present a brief therapeutic approach.

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## Language

Language is an example of higher cortical function, and its development is based on a genetically defined anatomic and functional structure, and on verbal stimuli provided by the environment.[2]

Language is a means of communication, that is, it is a social instrument of interaction used for communication. Thus, language should be regarded as a dynamic force or process instead of a product. It may be defined as a conventional system of arbitrary symbols, combined systematically to store and exchange information.[3]

## Language development

Before children can speak, they use their eyes, facial expression and gestures to communicate with others. They can also distinguish sounds of speech. Learning the linguistic code is dependent upon the acquired knowledge about objects, actions, places, properties, etc. It results from the complex interaction between innate biological abilities and environmental stimuli, advancing according to neuropsychomotor development.[1,4]

Although the level of efficiency with which language is acquired, is not well established, it is common knowledge that children from different cultures follow

the same global path of language development. While still *in utero*, they learn the sounds of their native language, and in their first months of life, they distinguish these sounds from those of other languages.[3,5]

Two distinct phases of language development exist: the prelinguistic phase, with vocalization of sounds but no words, which persists up to the 11-12th month of life; and the linguistic phase, when infants start to utter single but meaningful words. Later on, language expression becomes complex. This is a continuous process that occurs in an orderly and sequential fashion, with considerable overlapping of different developmental stages[6] (Table 1).

Language acquisition encompasses the development of four interdependent systems: pragmatic (communicative use of language in a social context), phonological (perception and production of sounds to form words), semantic (processing of meaning), and grammatical (use of syntactic and morphological rules to combine words into meaningful sentences). The phonological and grammatical systems constitute the language form. The pragmatic system describes how language should be adapted to specific social situations in order to convey emotions and reinforce meanings.[5]

Intention to communicate may be expressed nonverbally through facial expression, signs, and also by children's ability to answer questions, wait for their turn, make questions and discuss their point of view. This communicative competence shows that knowing to adapt language to a given situation and knowing the rules for social communication is as important as semantic and grammatical awareness.[3]

***Biological aspects of language***

The language process is quite complex, and consists of a neuronal network distributed through different regions of the brain. In contact with environmental sounds, speech is comprised of multiple sounds that occur simultaneously at different frequencies and with increased variability. The ear must tune into this complex

**Table 1 -** Language development

| Receptive | Age | Expressive |
|---|---|---|
| Gets scared easily.<br>Calms down when hears the sound of a voice. | 0-6 weeks | Differentiated crying and primitive sounds.<br>Appearing of vowel sounds (V). |
| Turns to the source of the voice.<br>Attentively observes objects and facts of the environment. | 3 months | First heard consonants (C) are p/b and k/g.<br>Starts babbling. |
| Answers with emotive tones to the maternal voice. | 6 months | Babbling (sequences of CVCV without changing the consonant). E.g.: "dudada". |
| Understands simple requests through gesture tips.<br>Understands"no" and "bye." | 9 months | Reproduces sounds.<br>Jargon.<br>Non-reduplicative babbling<br>(sequence of CVC or VCV). |
| Understands many familiar words and simple orders associated to gestures. E.g.: "Come with daddy." | 12 months | Starts to produde the first words, like "duck", "papa" or "teddy". |
| Recognizes some parts of the body.<br>Finds objects when asked to do it.<br>Symbolic playing with miniatures. | 18 months | May have from 30 to 40 words.<br>Begins to use two word combinations "Ken water" (for "Ken is drinking water"). |
| Follows instructions involving two verbal concepts (which are substantives). E.g.: "put the glass in the box." | 24 months | Presents a vocabulary with approximately 150 words.<br>Uses combination of two or three. |
| Understands first verbs. Understands instructions involving up to three concepts. E.g.:"put the big doll on the chair." | 30 months | Often uses telegraphic language ("Pig say oink", "Daddy go?"). |
| Recognizes several colors. Recognizes plurals, pronouns that differentiate gender, adjectives. | 36 months | Begins to use articles, plurals, prepositions and auxiliaries verbs. |
| Begins to learn abstract concepts (hard, soft, smooth).<br>Language used for reasoning.<br>Understands "if", "why", "how much."<br>Comprehends 1,500 to 2,000 words. | 48 months | Builds correct sentences, ask questions, uses negative forms, talks about events of the past or anticipates happenings. |

auditory signal, decipher it and translate it into electric impulses, which are carried by nerve cells to the auditory region of the cerebral cortex (temporal lobe). There, impulses are reprocessed and transmitted to language areas, where the acoustic signal is probably stored for a certain period of time.[2]

Wernicke's area, in the temporal lobe, recognizes the pattern of auditory signals and interprets them until concepts or thoughts are obtained, activating a distinct group of neurons for different signals. Neurons are also activated in the lower portion of the temporal lobe, forming an image of what was heard, whereas neurons in the parietal lobe store related concepts. According to this model, the neuronal network forms a complex processing unit.

The inverse process is necessary for verbalization of thoughts. Initially, there is an inner representation of the topic, which is organized into Broca's area, in the lower portion of the frontal lobe and converted into patterns of neuronal activation necessary for the production of speech. Areas responsible for motor control and memory are also involved in language development.[7]

The brain is a dynamic organ that is always adapting to new information; consequently, the areas associated with language in adult individuals might not be the same in children. Some brain zones might be used only during language development.[8]

The left hemisphere is believed to be language dominant in approximately 90% of the population, however, the right hemisphere is responsible for processing information, especially with respect to pragmatic aspects.[9,10]

## Etiology of oral and written language disorders

Speech involves articulation, resonance, voice, fluency/rhythm and prosody. Language difficulties are among the most frequent developmental disabilities, affecting 3-15% of children. They may be classified into delay, dissociation, and deviance[11] (Table 2).

The etiology of language and learning disorders varies considerably, and may include organic, intellectual/cognitive, and emotional factors (relational familial structure), and these factors are most times correlated. Learning disabilities may co-occur with other conditions (mental retardation, emotional disorders, sensory/motor disorders) or may be exacerbated by external factors, such as cultural differences, poor or inadequate education[12,13] (Table 3).

### *Language and epilepsy*

The effects of epilepsy, seizures and electroencephalographic discharges on language have been widely discussed in several studies. The most frequent disorders observed in epileptic patients are: developmental dysphasia associated with epilepsy; acute aphasia (transient dysfunction of the cognitive function), and acquired epileptiform aphasia (Landau-Kleffner syndrome).[14,15] Acquired epileptiform aphasia is characterized by deterioration of spoken language associated with seizures or abnormal epileptiform electroencephalographic activities, being often mistaken for autistic syndrome or hearing impairment. On top of deterioration of speech and auditory agnosia, behavioral disorders, including autistic traits, are also observed. Therefore, it is essential to keep an eye on children who have language regression, evaluating them carefully so that a differential diagnosis is established and proper treatment is provided.[16-18]

**Table 2 -** Classification of language alterations

| | |
|---|---|
| **Delay** | Progression in language follows the correct sequence, but in a slower rhythm, with performance similar to that of a younger child. |
| **Dissociation** | There is a significant difference between language evolution and other development areas. |
| **Deviation** | Development pattern presents a higher number of alterations: a qualitatively anomalous language acquisition is verified. It is a common finding in communication disorders of the autistic spectrum. |

### *Language and autism*

Language regression is observed in Landau-Kleffner syndrome and in autistic regression.[14,19,20] Recent studies, which focus on the language of verbal children on the

autistic spectrum, emphasize aberrant features of their speech such as

unusual word choices, pronoun reversal, echolalia, incoherent discourse, unresponsiveness to questions, aberrant prosody and lack of drive to communicate.[21,22] Several studies attribute the lack of speech of some individuals to the severity of their autism, mental retardation, or to an inability to decode auditory language.[21] In autism, comprehension and pragmatics are always affected, and findings include aberrant prosody, immediate or late echolalia and perseveration (inappropriate repetition of a utterance). Other symptoms, which are different from those observed in children with speech delay, are nonverbal communication disorders, stereotyped and persistent behaviors, restricted and/or unusual interests and impaired social interaction.[23] Our conclusion is that language regression in children is a severe disorder with significant long-term comorbidities.[24]

### *Intervention in children with speech disorders*

Speech and language development may be appropriate or not, depending on chronological age.

**Table 3 -** Etiology of written and verbal language disturbances

| Disturbance | Description |
|---|---|
| Environmental cause | Social and emotional risk factors. |
| Isolated delay of the expressive language ("constitutional") | Delay of non-demonstrable cause associated to normal comprehension, pragmatics, and nonverbal development. |
| Cognitive deficit | In the first years, language evolution in a child with delayed development is similar to the evolution of a normal child, but in a slower rhythm. |
| Auditory deficit | Influences language acquisition after 6-9 months, when changes in vocalization are observed (loss of vocal quality, consonants that disappear or simply don't appear, modification of vowel sonority) untill only primitive and guttural sounds persist. |
| Autism | Immediate or late echolalia, perseveration (inappropriate persistence on the same subject) associated to alterations of nonverbal communication, stereotyped and persistent behavior, and restricted and/or unusual interests may occus. Social capability is also affected. |
| Specific language alterations | Characterized by significant limitations of the linguistic function which cannot be related to the auditory loss, cognitive deficit, or changes of the fonatory structure and function. It is an exclusion diagnostic. |

Evaluation should include cognitive and emotional aspects of development, which may indicate or not the severity of the disorder, as well as the necessity for specialized family guidance and/or speech therapy.[24] It is widely known that early language stimulation may prevent learning disabilities, dyslexia, and developmental disabilities. A body of research has demonstrated the importance of the first three years of life to the development of the human brain.[25,26]

The basic interventions include the evaluation of language development at all levels, family and school guidance, and therapy.[1,24] Types of therapy include speech therapy (phonetic and phonological deviations), voice therapy (dysphonias), oral motor therapy (eating disorders, breathing and mobility of phonoarticulatory organs), oral speech therapy (expressive and/or receptive language) and written language therapy (dyslexias, dysorthographies and dysgraphias).

All stimulation activities in a child's speech therapy must be carried out in a playful way (e.g.: games), so that children find them amusing, and should encourage the participation of family and school, if necessary.[1]

Stimulation through singing, talking, playing games, and reading allow for the acquisition of skills that foster development. For the process of communication to occur, children need to be motivated. There should be the so-called intention to communicate (children can obtain their objects of interest through language). This occurs through the daily contact with people and through the stimuli that such interaction provides. The importance of breastfeeding, foods with adequate texture and consistency at different stages, and the elimination of thumb sucking or pacifiers at the age of two years should also be emphasized. All of these factors contribute to an orofacial musculature that facilitates speech development. Family has a crucial role in stimulating speech; it is the physician's or therapist's decision to let the family get involved or let himself/herself be involved by the family.[26]

## Learning

According to constructivism, learning is construction, action and awareness of the coordination of actions, where knowledge is built from learners' personal experience, with a previous learning structure or conditions, in addition to exposure to the necessary learning contents.[27]

Specific reading and writing development is related to a wide series of factors, which are underpinned by the mastery of language and capacity of symbolization, and that depend on internal and external conditions.[28]

### *Normal development*

Reading skills are verified by child's ability related to decoding, fluency and written comprehension.[29] Normal reading occurs in two phases. First, the graphic stimulus is visually processed. Afterwards, linguistic processing takes place, where letters are converted to sounds through

the nonlexical route, and then words are globally read as to their meaning via the lexical route.[30,31] The child should find out that some letters do not correspond to the speech sound, since "alphabetical reading associates an auditory phonemic component with a graphic visual component, which is known as graphophonemic correspondence".[32] It is necessary to be aware of the phonemic structure of language (word segmentation) and of the auditory units represented by different graphemes.[33]

***Neurobiological aspects***

The process of written language acquisition, as occurs with oral language, involves various regions of the brain, including the parieto-occipital area. In the occipital region, the primary visual cortex is responsible for processing graphic symbols, and parietal lobe areas are responsible for visuospatial aspects of writing. This processed information is recognized and decoded by Wernicke's area, which is responsible for language comprehension, and the expression of written language requires the activation of the primary motor cortex and Broca's area. For all this process to occur, intra-hemispheric connections must be intact.[7]

A study conducted with healthy individuals asked to read pseudo-words revealed activation of the left inferior frontal region; parieto-temporal region, involving the angular and supramarginal gyri, and posterior portion of the superior temporal gyrus; and occipito-temporal regions, involving mesial and inferior portions of the temporal and occipital gyri.[27] The same study was carried out with dyslexic patients, and revealed an increase in the activation of the inferior frontal gyrus and little activation of posterior regions.

Researchers have shown that as far as neurological mechanisms involved in reading disabilities are concerned, hemispheric asymmetry produces an atypical organization of the right hemisphere in dyslexic children and adolescents.[34]

Dyslexics have a temporo-parieto-occipital disconnection and a disconnection with the left frontal cortex, as well as other problems between the temporo-parietal cortex and the cerebellum and other brain regions.[33]

***Written language disorders in childhood***

Learning disabilities refer to the abnormal development of reading and written skills, and logical and mathematical thinking, and may be associated with oral language impairment.[34-36]

When investigating oral language disorders, it is common to find predictors of subsequent reading and writing disabilities. Likewise, when we investigate the factors that predispose to reading and writing disabilities, questions about language learning difficulties are raised. It has been underscored that among oral language difficulties in children, phonological difficulties may interfere with later development of reading and writing skills, and not articulation disorders, as previously thought.[37]

*Dyslexia*

Reading and writing encompass complex cognitive skills, in addition to the ability to reflect upon the language in phonological, syntactic, semantic and pragmatic terms.

When children are introduced to writing they already master the oral language, being therefore able to learn how to write. However, we know that there are specific rules that apply to writing, which make its learning more difficult.[38]

In Brazil, around 40% of children who are learning to write have problems with their school performance. This rate drops to 20% in industrialized countries.[38,39] If children with learning disabilities are properly followed by health professionals and educators, conjointly with the family, they can succeed in school.[13]

As a matter of fact, there is a combination of biological and environmental factors in written language acquisition, including motor integrity, sensory perceptual integrity and social and emotional integrity (actual possibilities offered by the environment in terms of quantity, quality, and frequency of stimuli). Moreover, the mastery of language and the ability to interpret symbols are important for the development of reading and writing skills.[40,41]

Dyslexia is a learning disability characterized by specific reading and writing difficulties. There are two types of dyslexia: developmental dyslexia and acquired dyslexia.[38,42] Developmental dyslexia refers to reading and writing disorders of environmental origin (related to learning style). In this case, reduced reading ability is associated with cerebral dysfunction, denoting a specific problem with the development of reading skills, and consequently, with learning to read.[33] Some authors think genetic factors are implicated in the etiology of developmental dyslexia. In acquired dyslexia, acquired reading and writing skills are lost, due to brain damage.

Several factors related to the etiology of developmental dyslexia have been under investigation, including cognitive deficits, neurological (neuroanatomical and neurophysiological) factors, premature birth, low birthweight, genetic and environmental factors. However, external (environmental) factors cannot be dissociated from neurological problems, since aspects such as poor education, emotional disorders, and poor stimuli during childhood may cause differences in the neurological and cognitive development, leading to severe reading disabilities.[41,43,44]

Dyslexias may be of two types: central and peripheral (Table 4). In central dyslexias, linguistic processing is undermined, that is, the letter-to-sound conversion is impaired. In peripheral dyslexias, the visual perceptual

**Table 4 -** Classification of central and peripheral dyslexias

| Dyslexias | Clinical characteristics | Neuroanatomical characteristics |
|---|---|---|
| Phonological dyslexia | Phonological decoding incapacity.<br>Damages on grapheme-phoneme conversion.<br>Difficulties in performing tasks that involve phonologic memory.<br>Very bad performance on reading of non-familiar stimulus and pseudowords (non-real words). | Little is known about the neuroanatomic areas which are essential to an appropriate functioning of the perilexical processing. There is no evidence of specific neuroanatomic dysfunction. |
| Surface dyslexia | Impairment of the lexical route.<br>Stimuli are read through a phonologic process e.g. reading PINT to rhyme with hint etc).<br>Orthographic treatment of information is impaired. | Evidence of dysfunction in the middle temporal and postero-superior areas of the left hemisphere. |
| Deep dyslexia | Blockage on non-lexical route.<br>Absence of non-word reading.<br>Ability to read concrete and frequent words. | Some authors report the occurrence of multiple lesions in the left hemisphere, and others suggest that there are residual reading abilities in the right hemisphere due to an extensive lesion in dominant hemisphere. |
| Attentional dislexia | Ability to read single words is maintained.<br>Difficulties in reading multiple items when simultaneously displayed. | Left parietal lobe lesions. |
| Neglect dyslexia | Difficulties in reading on the visual field of the contra-lateral side of brain injury. | Lesion in the region of the middle cerebral artery on the right hemisphere involving the frontal, temporal and parietal lobes. |
| Literal Dyslexia (pure) | Letter-by-letter reading is maintained. | Inferior occipital lesions extensive to the left side. |

system is compromised, and the understanding of what has been read is then hindered.

Central dyslexias can be subdivided into phonological, surface, and deep dyslexias, whereas peripheral dyslexias are subdivided into attentional, neglect and pure dyslexias.[29]

With regard to developmental dyslexias, the most common ones are phonological dyslexia, surface dyslexia, and semantic dyslexia. The latter is characterized by reading aloud, with perfect letter-to-sound conversion, but poor written comprehension.[45]

Several studies have provided evidence of phonological deficits in developmental dyslexia. Nevertheless, recent studies have gathered evidence of multiple temporal processing deficits in dyslexias. Actually, dyslexics have visual and auditory disorders, which may result from generalized problems with perception and selection of stimuli.

Dyslexic children have auditory and visual disorders related to spatial orientation. These findings suggest that poor utilization of allocated space may tamper with the development of phonological and orthographic representations that are essential to reading acquisition.[46]

A study conducted by the Institute of Cognitive Neuroscience (London) assessed 16 dyslexic adults and 16 controls by submitting them to a full battery of psychometric, auditory, visual and cerebellar tests. Individual data showed that all dyslexic individuals had phonological deficits, 10 individuals had auditory deficits, four had motor deficits, and two of them had visual deficits. These findings suggest that phonological deficits

may occur in the absence of any other motor or sensory disorder, and may cause significant literacy impairment, as demonstrated by five of 16 dyslexic individuals.[47]

*Dyslexia and attention deficit hyperactivity disorder*

Most children with attention deficit hyperactivity disorder have difficulties in school. Learning disabilities may co-occur with developmental dyslexia.

A comparative study was carried out with children who had reading disabilities but no attention deficit hyperactivity disorder, children who only had attention deficit hyperactivity disorder, children who had reading disabilities and attention deficit hyperactivity disorder, and children without any disabilities. The auditory processing in the temporal lobe of these children was investigated. The results did not show a deficit in the auditory temporal functions in children with reading disabilities, but they suggested that the presence of attention deficit hyperactivity disorder is a relevant factor for the performance of children with reading disabilities.[48] Another study conducted in Holland (Department of Special Education Vrije Universiteit Amsterdam) revealed that inhibitory deficits in lexical dyslexics might be attributed to frontocentral dysfunctions involved in motor inhibition, suggesting that there might be an association between lexical dyslexia and attention deficit hyperactivity disorder, since both groups present executive dysfunction.[45]

*Dyslexia and low birthweight*

In low birthweight infants, there exists an association between the presence of periventricular brain injury and low performance on reading and spelling tests.[49] A U.S. study sought to establish an association between reading disabilities and their potential risk factors in boys and girls. The results indicated that low birthweight girls had twice the risk of developing reading disabilities.[50] Differences have been found as to the use of the cortex during reading in low birthweight infants.[51]

*Genetic influences in dyslexia*

As some individuals have shown genetic susceptibility to reading disabilities, several studies have been made about dyslexias taking genetic factors into consideration. Reading has been ascribed to specific chromosomes (6, 1, 2, 15), even though there has not been any evidence so far of specific genes related to reading skills.[39]

Recent findings obtained from the Human Genome Project indicated four dyslexia susceptibility genes: DYX1, DYX2, DYX3 and DYX4. These genes are located in different positions, possibly showing the heterogeneity of reading disorders.[52]

Another study, carried out by neuropsychologist Frank Wood, from Wake Forest University, shows that other chromosomes (6, 1,2 and 15) are related to reading disabilities in some children.[52] More specifically, loci on chromosomes 6 and 18 have shown replicable effects on reading skills.[53]

It should be underscored that the improved knowledge about the role of genetics in dyslexia may help diagnose and treat susceptible children more efficiently and rapidly.

*Other written language disorders - dysgraphia and dysorthographia*

Written expression (assessed through copying, dictation, and spontaneous writing) can also help detect disorders such as dysgraphia (distorted or incorrect writing) and dysorthographia (spelling disability that is unexpected for a given age or level of education). Dysgraphia and dysorthographia may be associated or not with dyslexias.

***Interventions***

The basic principles of stimulation of written language among children are: to encourage discovery and use of logical thinking to build words and texts and represent phonemes; to provide them with opportunities to write and read spontaneously; to constantly explore different writing functions (not only production of texts, but also of letters and notes); and to show them the differences between spoken and written language. It is essential that children become aware that speech and writing are different forms of language expression.

As previously mentioned, problems with the perceptual reading processes or with psycholinguistic processes (lexical, visual, phonological, syntactic or semantic) may result in reading disabilities; in this case, the development of a rehabilitation program should be directly related to the assessment of children's deficits.[35] In patients with surface dyslexia, a lexical strategy is used, and in phonological dyslexics, the most appropriate strategy consists of the letter-to-sound conversion (nonlexical).[54] The stimulation of phonological awareness in pre-readers is of paramount importance, since various studies have demonstrated its efficiency in reading acquisition.[55]

Currently, the most recommended intervention for the treatment of children with written language disabilities is the direct approach to reading skills, combined with activities related to phonological processing. In the past, the practices sought to stimulate skills considered to be prerequisites for reading acquisition, such as visuospatial perception, psychomotor skills, etc.[56]

All activities that stimulate written language should be carried out in a playful way (games), so that children find pleasure in reading and writing. At home, parents should encourage their children to read by reading them stories, playing rhyming games that help with phonological awareness, playing games with letters and drawings for them to get acquainted with writing, having them read

labels and ads; in brief, children should never be obliged to read a book; they should be encouraged to read it in order to know what the story is all about, instead.[29]

## Conclusion

There are various causes for language disorders and learning disabilities, although many studies indicate that neurological factors might be implicated. Improved knowledge about the neurobiology of language development and learning processes will certainly contribute to a better therapeutic approach to these patients. Systematic investigation aimed at an accurate diagnosis may guide health professionals in choosing the best treatment for each case.

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