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ADHD and Impact on Language

Clay Brites

Abstract

The language problem in ADHD could be expressed in any age, in different intensity levels, that could bring negative effects in all daily activities and learning process, which depends on the right language acquisition during the child's development. Among the most common comorbidities in ADHD, the abnormalities in language result in greater unsatisfactory evolution and many problems in verbal and nonverbal abilities, and even more in academic life, as a result of losses in reading and writing appropriation.

Keywords: comorbid language, ADHD, language, cognitive processing, neuropsychological assessment

1. Introduction

The attention deficit hyperactivity disorder (ADHD) is a neurobiological condition, which starts in childhood and youth phase, derived of genetics and external factors, that features an attention, hyperactivity, and impulsivity deficit excess [1]. It hits worldwide an average of 6–10% of children and 2.5–4% of adults [1, 2]. It also causes emotional self-regulation problems, executive impairment, and space and motor disorganization and may cause language problems in 30–40% of the cases [3].

The language problem in ADHD could be expressed in any age, in different intensity levels, that could bring negative effects in all daily activities and learning process, which depends on the right language acquisition during the child's development. Among the most common comorbidities in ADHD, the abnormalities in language result in greater unsatisfactory evolution and many problems in verbal and nonverbal abilities, and even more in academic life, as a result of losses in reading and writing appropriation [4].

Thus, it is essential to understand the facts that interrelate ADHD with the cognitive and language development process, or particularly where and how ADHD neurobiological dysfunctions affect the dynamic of the neural network responsible for the receptive, integrative, and expressive language structure in different child neurodevelopment levels.

2. The neurobiological aspects of ADHD

ADHD leads to emotional and cognitive self-regulation problems, which affect the executive attention and operational memory in the performance of

discretionary, routine, and habitual activities. Tasks with no immediate reward which are, at the same time, necessary, priority, and essential for the development of basic abilities and general learning, adding the capacity of self-engage for whole process conclusions [5].

The cause of this disorder is still unknown but is generated by the interaction between genetic and environmental factors (**Table 1**) and by similar epigenetics mechanisms in neuropsychiatry diseases, and they are caused by polygenic inheritances of irregular transmission and are influenced by the environmental and gender predispositions. In the case of ADHD, the predominance is male, in the ratio of 4:1 [6]. So even without a specific cause, these abovementioned data in conjunction with epidemiological evidence provide to the specialists and international consensus a safe outline to the genetic and environmental risk factors for ADHD development (**Table 1**) [7]. The knowledge about these factors contributes for the clinical surveillance during early childhood in order to observe the possibility of the appearance of the first symptoms, adolescence, and adulthood.

The symptoms and cognitive-behavioral changes of ADHD are the results of abnormalities in several neuronal connections, both cortical and subcortical, which can lead to functional impairments in one or more brain regions at the same time. The most affected and described connections mainly involve the anterior cingulate gyrus, prefrontal cortex, amygdala, striatum, and ventral integumentary area, that is, both voluntary and involuntary regions of attention that regulate the intensity and support of the attentional focus [8]. These regions are interconnected by the action of dopaminergic and noradrenergic neurotransmitters, and their deficits also contribute to lowering the attentional functional of ADHD. Added to them are the maturational delays that can gradually occur in these connections during the first years of life and which are observed in many research-based evidences in the functional neuroimaging of the brains of children with ADHD when compared to typical children. The pace of neuronal and connective maturation is slower, erratic, diffuse, or delimited and can emerge clinically at different times in the life cycle, from early childhood to late adolescence [8, 9].

Neuroimaging exams, much more developed today because of the technological advances associated with neuroscientific research, such as functional magnetic resonance imaging (fMRI), are able to analyze the maturational dissonance present in groups with ADHD from a comparative perspective with case controls. There are also brain morphometry, cortical thickness index, diffusion images (tractography), surface measurements of brain areas, gyration index, and geodetic mapping. These methods have shown that ADHD leads to microstructural changes and modifies the proportions between the functional regions of the brain [10, 11].

Genetic factors	Environment factors
High heritability (76%)	Prematurity
Association between twins (80%)	Low birth weight
Carrier parents (85%)	Perinatal complications
Average prevalence in countries (5.2%)	Maternal smoking
Associated with genetic syndromes	Unstable and needy environments
Associated with 20 genetic mutation	Drug use during pregnancy

Table 1.
Genetics and environments risk factors for ADHD clinical features.

Thus, the various changes present in ADHD can be summarized as dis-maturational, connectives and productive, and abnormal bioavailability of neurotransmitters in the cortical (top-bottom) and subcortical (bottom-up) networks.

3. Neuropsychological and endophenotypical behavioral aspects of ADHD

If we have a different and inefficient brain to process information, the next question would be: In what and how would it be different? In what functional aspects? What neuropsychological deficits are predominantly present in ADHD?

As there are still no specific biological markers, the description and clinical definition of ADHD is based on the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) criteria (**Figure 1**) on neuropsychological assessments and on the construction, since the early 2000s, of possible candidate profiles to be its endo-phenotypes [8, 12]. These parameters help to establish the diagnosis and understand its functional deficits.

ADHD can lead to three major functional deficits: (1) executive attention deficit, (2) operational memory problems, and (3) self-engagement in sequential tasks without reward [13].

Executive attention is responsible for the ability to increase the degree of sensitivity, directing the brain perceptions, and persisting in these analyses, being able to verify the details and the most significant information of any task. It includes selective, sustained, alternating, divided, covered, and spatial attention and is able to manage focal points according to time, space, and priorities. It depends on the connection integrity of frontal areas with the anterior and striated (subcortical) cingulate regions.

Operational/working memory is the ability to immediately memorize sequential information to fully accomplish it without forgetting the most important, decisive priority details and those that require data from other axes of knowledge, seeking to align them with those already memorized. It depends on the integrity of frontal regions with amygdala-hippocampus-striatal connections.

Self-engagement in sequential tasks without reward is the “energetic” amount of self-effort and intention undertook to fully and correctly fulfill a specific activity, task, or request without a greater motivation, or which represents a routine, rule, or command by an authority or institution. We can also call it cognitive self-regulation and it depends on connections between regions of the prefrontal cortex with the striatum, ventral regions of the anterior cingulate cortex, amygdala, and ventral tegmental nucleus.

The ADHD patient has a deficit in these three abilities and, therefore, the presentation of its clinical condition and functional difficulties are predominantly concentrated in executive functions, problems in working memory (verbal and nonverbal), difficulties in executive attention, and insufficient surveillance to fulfill correctly activities without immediate attractiveness or pleasure. Even though these characteristics are well defined, there is still no single endophenotypic pattern for ADHD or a neuropsychological profile. However, this evidence is sufficient to better understand the diagnostic approach in clinical suspicion, which evaluation methods to request, and in interdisciplinary evaluations, how to understand the deficits and discrepancies present in each of them and to associate with the main complaints of the child and the child's school.

Thus, in the neuropsychological evaluation, we have to use the instruments that can measure selective and sustained attention, executive functions, verbal and

The diagnostic criteria of the DSM-5 include 9 signs and symptoms of inattention and 9 of hyperactivity and impulsivity. Diagnosis using these criteria requires ≥ 6 signs and symptoms from at least one group. In addition, it is necessary that the symptoms:

- Be present often for ≥ 6 months
- Be more expressive than expected for the child's level of development
- Occur in, at least, 2 situations (for example, home and school)
- Be present before the age of 12 (at least some symptoms)
- Interfere with the functional capacity at home, at school or at work

Inattention symptoms:

- Does not pay attention to details or makes careless mistakes in schoolwork or other activities
- Has difficulty in keeping attention on tasks at school or during games
- Doesn't seem to pay attention when approached directly
- Does not follow instructions and does not complete tasks
- Has difficulty organizing tasks and activities
- Avoid, dislike or is reluctant to engage in tasks that require maintenance of mental effort over a long period of time
- Often loses objects needed for school tasks or activities
- Easily distracted
- Forgetful in daily activities

Symptoms of hyperactivity and impulsivity:

- Moves or twists hands and feet frequently
- Often moves around the room or other places
- Runs and climbs too often when this type of activity is inappropriate
- Has difficulty playing quietly
- Often moves and acts with euphoria
- Tends to talk too much
- Frequently answers questions abruptly, even before they are completed
- Often finds difficulty to wait for his turn
- Often interrupts others or intervenes in other people's talks

The predominant inattention type diagnosis requires ≥ 6 signs and symptoms of inattention. The diagnosis of the hyperactive/impulsive type requires ≥ 6 signs and symptoms of hyperactivity and impulsivity. The combined type diagnosis requires ≥ 6 signs and symptoms for each criterion of inattention and hyperactivity/impulsivity.

Figure 1.
ADHD DSM-5 criteria. Source: Refs. [18, 19].

nonverbal working memory, reaction time, and cognitive flexibility. Furthermore, correlate these assessed skills with the behavior of the assessed person during the exam, their reactions, avoidances, profile of behavioral responses to failure and test prolongation, etc. The description of these behaviors should be part of the feedback for the specialized team and will be useful for the conclusions.

4. The impact of ADHD on language neurodevelopment in childhood and school

After it all, and the language? The child's learning, from a young age, in the early years, depends on several factors and, neurobiologically, in his first contact with the world, he needs his sensory and perceptual functions. Vision, hearing, touch, etc. and its perceptual centers in the brain added to the qualitative perceptual functions as well, such as attention and memory, to correctly absorb and fix the selected stimuli in the brain. Language, in this context, results from its innate abilities (presence of a network and integral structure for the language) and the internalization of the "languages" perceived around it. Little is known yet whether ADHD affects more innate or acquired language, but in several comparative studies associating both conditions, it appears that ADHD influences the appearance of language disorders (LDs) much more than the opposite [14, 15]. There are sufficient data demonstrating that, in groups of children with LD, there are proportionally fewer children with ADHD than when evaluating groups of ADHD seeking to verify the presence of LD [16].

The adequate construction and the full development of language structuring processes in childhood depend heavily on attentional, executive, and working memory processes. The union of all these factors in the construction of language can be understood by several psychological theories and theoretical constructs, but it is well summarized in the **phonological buffer** [15, 17, 18]. In language science, the phonological buffer is a neurobiological and cognitive mechanism of language composed of skills that align and influence each other as a dynamics of weights and balances for the perception, memorization, and integration of linguistic sensory stimuli contributing to the development and consolidation, in memory, of processes associated with language structures in a coherent way. Consolidated, this same buffer triggers the emergence of previously selected and memorized phonological data to be used for a given expressive activity in an organized and sequential manner (speaking, reading, writing, etc.).

The skills that make up the buffer are executive attention, working memory, and phonological awareness (**Figure 2**). Among the three, the first two are functions specifically associated with ADHD. In ADHD, both are deficient, unstable, and functionally oscillating and end up negatively influencing the development of speech and language in the early years of life, which are skills that depend on phonological awareness and therefore affect the cognitive processes of language.

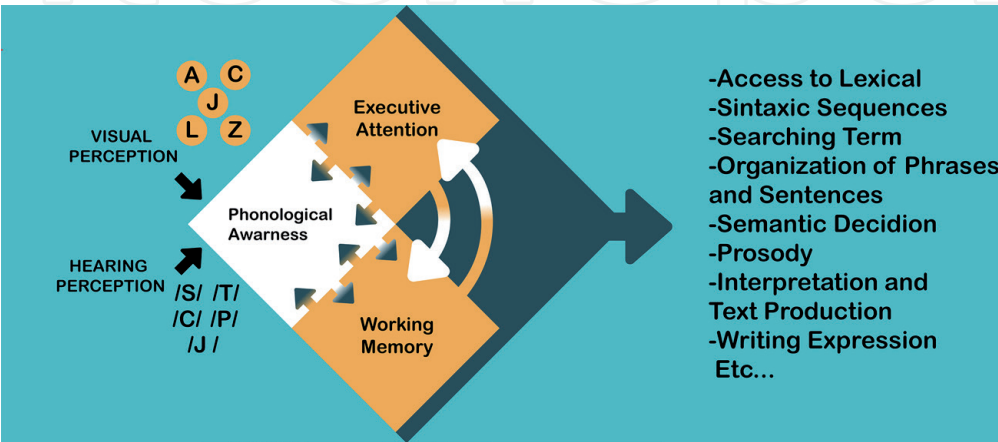


Figure 2.
Interrelation among executive attention, working memory, and phonological awareness to building reading and writing.

In this context, it seems that the selective and sustained attentional deficit would be the main center of disfunction. Attention selectively focuses on one aspect of information and excludes the other. The child who is learning the language from an early age must be able to selectively focus on relevant linguistic information and naturally ignore irrelevant information. He/she must sustain this focus to form an association between an object and a label in the word learning process. When the input source of the language or object changes, the child must also be able to draw attention away to avoid losing relevant information. As language develops, he/she must be able to attend linguistic sequences and social routines for the development of grammatical and pragmatic skills. If he/she cannot do this, whether due to attention deficits or early language problems, the process of language acquisition and consolidation will be fragmented and deficient.

There are also other factors that associate ADHD with language from a genetic and developmental point of view. Children with ADHD may have, in up to 40% of cases, speech development delays because it can affect the perception of sounds during the speech of his peers and caregivers, generate joint problems, and increase chance of stuttering; and by forming phonemes and syllable junction, it is possible to observe a greater slowness in syllabic awareness in these patients [19]. This means the disorder affects attention, motor control (inhibitory and rhythm), and working memory, eventually leading the referred gaps in the evolution of the articulatory and phonological organization.

Another factor described would be the presence of mutations and other genetic abnormalities between both conditions, which would lead to the transmission of their deficits present in the parent(s) to their children. And, finally, the separated association of both conditions that were generated in the same child without one being incidental to the other, but both sharing dysfunctions in specific areas in their interaction, participating in reading and writing language-related functions and language structure [20].

5. Aspects of language influenced by ADHD

Several publications and researches show language alterations in ADHD patients [21]. There is still a need for greater research about the genetic or environmental factors involved. Some evidence describing genes that appear to be at the interface of both conditions already exists, such as FOX2 and CNTNAP2 [22]. But they still lack models that really demonstrate the solid link between them, what kind of comorbidity is included, and what genetic relationships exist (and, specifically, with which genes or mutations). For now, the most common studies are based on relative risk measures (RRs) and odds ratio (OR), and in these, they observe risks of two to six times greater language problems in ADHD groups when compared to controls [19].

ADHD can affect four axes of language in childhood and adolescence: (1) delays in speech acquisition and language structuring (mainly articulatory, phonological, lexical, and morphosyntactical but also, in a second plane, pragmatical); (2) hearing processing disorders; (3) abnormalities in speech (speech, voice, and fluency); and (4) deficits in the linguistic processes involved in the appropriation of reading and writing and math learning (**Table 2**).

In research conducted with 76 children with ADHD and an average age of 11 years old, Bruce e cols. (2006) observed that more than half of them were accompanied by a speech therapist and the rest did not receive any intervention. The results showed that most children had problems in pragmatic language, language comprehension with greater receptive communication deficits and delays, and learning gaps in reading and writing. In this same work, cognitive tests were carried

Axes affected in speech therapy	ADHD effects
Delays in acquiring speech and language during development	Delay in speech acquisition, articulatory errors, memory deficit, and phonological manipulation, problems with rhythm and self-control to speak
Disorders in auditory processing	Deficits in integration, temporality, and association of sounds
Abnormalities in speech	A deficit in pragmatic language and in the perception of prosody during the speech, disrespect to the shifts of conversation, loss of significant moments to understand the intention of the speech, disorganization in the sequence of who will speak, frequent forgetfulness, and long-winded speech
Deficits in the language of reading and writing	Slowness in literacy, delayed processing and spelling engine, poverty in the interpretation and production of texts, spatial trouble remembering quotes and locations in terms of text, and little memorization of facts, concepts, rules that make up the reading and writing

Table 2.
Four axes of language in childhood and adolescence affected for ADHD.

out and the evidence showed that the pragmatic losses were due to the inattention and impulsive behavior of ADHD [23]. There are at least seven ADHD symptoms present in the *DSM-5*, which are indicative of problems associated with communication and language: (1) does not seem to hear when talking directly to him/her; (2) difficulty in carefully following instructions; (3) rush to answer before the questions are even finished; (4) interrupts or intrudes on the conversation of others; (5) difficulty in waiting for dialog shifts; (6) speaks excessively and without self-control; and (7) difficulty in playing silently. Such symptoms have a major negative influence on the construction of communication skills, which can be consolidated during child development and adolescence and remain altered throughout life [2].

Besides, the existence of speech delay, articulatory problems, and stutter are relatively frequent in ADHD. Researches show that 25–40% of the cases suffer from such alterations and that indicates possible harm in complex acquisition with aging until it becomes predisposed comorbidity with dyslexia [24]. Many children with ADHD need speech therapy in their early ages of life, and a great part of them keep the therapy until the beginning of school and literacy years, but demonstrations show that with early intervention, the prognostic can get much better [25]. Pieces of evidence show larger deficits in the phonological and articulatory abilities, semantic structure, vocabulary repertoire, reading comprehension, and pragmatic process during dialogs and discursive abilities [26, 27].

The hearing processing is a set of specific and nonspecific skills associated with the set of skills necessary for an adequate perception, integration, and interpretation of what is heard in the most diverse environments. ADHD, due to its characteristics, especially affects the nonspecific skills necessary for auditory processing: the integrative, temporal, and organizational aspects of auditory discrimination. Almost 50% of cases of auditory processing disorders have comorbid symptoms of ADHD and their treatment requires intervention in both for good results to occur [28, 29].

Regarding discursive skills, several changes are observed in people with ADHD. Problems in sustained attention, impulsiveness to conclude and accelerate the discursive times and attentional lack of control, and seeming not to hear the interlocutor make these patients have greater difficulty in applying the right words and expressions at the right time and with plausible intentionality. Through it away occurs both to listening and delivering speeches and, especially, in the consistent persistence of the records heard, they show sudden and erratic self-distractions,

little perception for moments of exclamations and tangential comments, hum and make strange noises during the process, enters with new topics decontextualized, and have little sensitivity to perceive commotions during the speech [2]. These difficulties can lead to great losses in the classroom, in lectures, in the coordination of speeches during a comment, and in the correct and strict understanding of a dialog or a recommendation or even “scolding” or warnings from your parents or caregivers. Perhaps, this explains why these patients tend to repeat the same mistakes or do not understand small insinuations or messages contained in the speeches that they hear and receive severe and repeated criticisms in social relations for this.

The significant problems and deficits observed in the processes of learning to read and write and, even later, in the literacy phase and in the already consolidated phase of the acquisition of these skills in these patients are varied and numerous—and today well described—in the scientific literature. People with ADHD have delays and gaps in the process of acquiring and appropriating basic skills for learning to read and write in up to 30–40% of cases. We see little memorization of graphic and phonemic symbols, difficulty in joining letters, and graphophonemic decoding. They usually forget much of what they saw or heard in class and can evolve greater irregularity so that they will acquire the proper fluency and automatic word recognition, sentences negatively affecting the ability to interpret, assimilate statements, and produce texts coherently. They may have more difficulty in organizing the words and phrases sequentially and “lose themselves” in the cohesion of the set of information they write in addition to often not being able to remember all the significant details to clarify an argument in writing.

Not being able to remember orthographic rules or perceive prosodic circumstances in the text to properly apply punctuation or paragraphs are constant in ADHD and can damage the semantic-pragmatic nexus. The longer and subliminal the writings, the greater the difficulties in textual praxis and the subsequent errors. Not to mention the problems of graphomotor coordination generated by the problems of rhythm, persistence, and inhibiting self-control of manual writing mobility, which in addition to deteriorating handwriting, leads to early tiredness, pain in the limb, and aversion/displeasure toward writing. They do not even take care of their writing tools because they lose, break, and play more with them in their hands. By making use of them at the time of class, they confusingly drop, destroy, and barely manage to stay at your desk during the class period. Furthermore, as they usually strain to perform in a less productive/in-depth manner than their colleagues, their text ends elementary, without details, abbreviated, saving words and, even so, they think what they have done is great and “enough”; but, actually, it had resulted in an insufficient work that is poorly done and that had to be corrected. Persistent, recurring delays lead to a progressive inadequate acquisition of skills and many of these young people progress to learning disorders [19].

All of this evidence can help to understand why ADHD patients act socially more with their hands (by actions) than with their eyes and mouth (by structuring words and arguments) and then being less assertive, wordy, and emotionally loosely organized in social interaction. Not to mention the significant losses in school performance, poor interpretation of statements, and low self-esteem for academic processes. The risk of school failures and dropouts is four times higher in these patients and reduces the chance of completing and receiving a university degree by up to eight times [30, 31].

Finally, the knowledge about these changes by health and education professionals is very important because the effects on the global development of the child’s language will lead to a negative, progressive impact in all related areas. The severe appearance of gaps in school learning, in the understanding of verbal and nonverbal processes of social communication, and the emotional and affective

relationships that depend on language skills can lead to subjective problems in the patient and in family dynamics with different impacts throughout his life.

6. ADHD and language: The role of speech therapy

In the face of all the observations and the aforementioned evidence, the hearing care professional should be prepared to evaluate these children. Delays in speech and language acquisition should always suggest the possibility of ADHD as well as the presence of quantitative and qualitative deficits in BP, speech skills, and reading and writing, depending on the chronological age. However, studies and publications on ADHD and aspects related to language around the world still lack, except on the area of reading, which is the only one with more robust studies [32].

There is still no protocol or consensual or systematic recommendations on how the speech therapist can act in this area. However, there are articles and publications that can help this professional to create a basic protocol to better direct their work and to assist in a complementary, more refined, and objective way for the interdisciplinary team in order to better conclude the diagnosis and more broadly direct future strategies' therapeutic [32, 33].

Even so, some recommendations can help, right now, to improve the procedures of speech therapy assessment in ADHD:

- 1. Knowing deeply the signs and symptoms of ADHD.
- 2. Knowing how to correlate the neurobiology and neuropsychology of ADHD with speech therapy assessment.
- 3. Track in the child's neurodevelopment early signs of ADHD and possible effects of ADHD on the child's speech and language.

Test name	Age	Domains evaluated
Clinical evaluation of language fundamentals—4	5–21 years	Formulation of sentences, the definition of words, and their classes and semantics
Test of language development primary	4–9 years	Semantics and grammar, reception and expression, and general language skills
Communication abilities diagnostic test	3–9 years	Varied tests for syntax, semantics, and pragmatics during stories, games, and conversations
Language processing test 3: Elementary	5–11 years	Association tasks, categorization, similarities/ differences, and multiple meanings and attributes
Children's communication checklist-2	4–16 years	Evaluates verbal and nonverbal social communication
Assessment of comprehension and expression	6–11 years	Understanding sentences, inferences, nonliteral language, and use of narratives
Test of language competence	5–18 years	Ambiguous sentences, comprehension, inferences, and figurative language
Test of pragmatic language	8–18 years	Pragmatic language
Test of attention, executive, and language functions	Under 5 years	Translated available tests, validated in neuropsychology and speech therapy

Table 3.
Instruments in speech therapy for language assessment in ADHD.

4. Knowing more clinically the signs of impaired reading and writing that may be associated with language problems or ADHD.
5. Interpreting the BP test while considering the nonspecific factors that may be negatively influencing the results.
6. Seeking consensus, new publications, and speech therapy forums or congresses that will systematize instruments to be used in the assessment of these children (instruments in speech therapy, even a foreign language, can help a lot) (Table 3) [21].

7. Final considerations

Knowing the aspects of ADHD related to the development, structuring and school management of language is essential for undertaking an adequate assessment of these patients during and after the diagnostic process. During, in order to decisively contribute to speech therapy data in the confirmation of a further condition without definitive biomarkers. After, in order to delineate with the results the treatment needs that may involve the speech therapist, who has the role of intensively intervening in deficits that are not within the competence of the school or family but should be corrected by the specialist in order to provide a more favorable and persevering school performance.

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