

**THE LANGUAGE NETWORK AND LEARNING  
DIFFICULTIES  
AN INTERDISCIPLINARY INTEGRATIVE APPROACH  
BETWEEN NEUROLINGUISTICS, NEUROLOGY, AND  
SPEECH THERAPY**

شبكة اللغة وصعوبات التعلم  
مقاربة بنيوية تكاملية بين اللسانيات العصبية وطب الأعصاب والأرطوفونيا

Dr. Naima Aichouche <sup>\*(1)</sup>

<sup>1</sup> University of El Oued (Algeria), [aichouche-naima@univ-eloued.dz](mailto:aichouche-naima@univ-eloued.dz)

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***Abstract:***

Diagnosing language-based learning difficulties in the early stages of education is one of the major challenges in linguistic and educational research. It oscillates between developmental disorders of neurological origin and environmentally induced delays that can be remediated. Building on this issue, the study adopts an integrative network perspective, employing the language network as a unifying theoretical framework that bridges neurolinguistics, neurology, and speech therapy. Through a critical review of contemporary research, the article demonstrates that each field has offered decisive tools: neurolinguistics has redrawn the map of the network through precise electrophysiological and imaging markers; neurology has delineated the boundaries between developmental, acquired, and degenerative impairments; and speech therapy has tested hypotheses through performance-based assessment and developed standardized protocols to measure intervention outcomes. However, these contributions, when considered in isolation, remain insufficient to yield an effective diagnosis.

The article proposes an integrative model that begins with an initial distinction between environmental and developmental factors, followed by the formulation of a neurolinguistic hypothesis, its medical refinement, and its performance-based testing, ultimately leading to a differentiated educational decision. The model provides original protocols tailored to the specificities of Arabic, which is based on the root-pattern system, thereby

opening prospects for more precise and effective diagnostic and educational practices.

**keywords:** Language Network; Learning Difficulties; eurolinguistics; Neurology; Speech Therapy; Integrative Network Model

### ملخص:

يمثل تشخيص صعوبات التعلّم اللغوية في المراحل المبكرة من التعليم أحد أبرز التحديات في البحثين اللساني والتربوي، إذ يتأرجح بين اضطرابات نمائية ذات أساس عصبي من جهة، وقصور بيئي قابل للتدارك من جهة أخرى، انطلاقاً من هذا الإشكال، تعتمد الدراسة منظوراً تكاملياً يجعل من مفهوم «شبكة اللغة» إطاراً نظرياً جامعاً بين اللسانيات العصبية وطب الأعصاب والأرطوفونيا.

وبالاستناد إلى مراجعة نقدية للأبحاث المعاصرة، يبيّن المقال أنّ كل مجال قدّم أدوات حاسمة؛ فاللسانيات العصبية أعادت رسم خريطة الشبكة عبر مؤشرات كهربائية وتصويرية دقيقة، بينما تولّى طب الأعصاب ضبط الحدود بين العجز النمائي والمكتسب والتنكسي، في حين اختبرت الأرطوفونيا الفرضيات عبر مقاييس الأداء وطوّرت بروتوكولات معيارية لرصد أثر التدخل، إلّا أنّ هذه المساهمات، تظل غير كافية لبناء تشخيص دقيق وفَعَال ما لم تُدمج في إطار تكاملي.

لذا يقترح المقال نموذجاً شبكياً تكاملياً يبدأ بالتمييز الأولي بين القصور البيئي والاضطراب النمائي، مروراً بصياغة الفرضية العصبية-اللسانية، ثم ضبطها طبياً واختبارها أدائياً، وصولاً إلى قرار تربوي مفصّل ومتمايز، ويؤكد هذا النموذج الحاجة إلى بروتوكولات أصيلة تراعي خصوصيات اللغة العربية القائمة على نظام الجذر-الوزن، بما يفتح آفاقاً لتأسيس ممارسات تشخيصية وتعليمية أكثر دقة وفعالية. الكلمات المفتاحية: شبكة اللغة؛ صعوبات التعلّم؛ اللسانيات العصبية؛ طب الأعصاب؛ الأرطوفونيا؛ النموذج الشبكي التكاملي.

## Introduction

The early years of primary education witness noticeable variation in the acquisition of reading, writing, and comprehension skills; some pupils make rapid progress, while others falter despite equal general intelligence and similar educational conditions. This disparity is due to the different nature of the difficulties: specific developmental disorders with a stable neurological basis, and delays of environmental–pedagogical origin that can be overcome. However, the absence of a strict interdisciplinary approach makes these subtle differences vulnerable to one-sided and incomplete diagnoses; developmental disorders are reduced to temporary reading deficits, or environmental delays are interpreted as permanent neurological impairments, which leads to ineffective educational interventions or inappropriate medical decisions.

Contemporary research has shown that the language network constitutes an interconnected brain system, mainly distributed across the left frontal and temporal lobes, with a distinctive selectivity for linguistic processing compared to general cognitive networks. This perspective has allowed neurolinguistics to develop precise hypotheses about phonological, syntactic, or semantic deficits, drawing on evidence from electrophysiological and imaging studies. Yet, this approach—despite its strengths—remains limited if applied in isolation from neurology, which identifies biological causes and distinguishes between developmental, acquired, and degenerative impairments, and from speech therapy, which tests these hypotheses through performance-based assessment and translates them into therapeutic and educational plans.

From this emerges the central problem:

How can the insights of neurolinguistics, neurology, and speech therapy be integrated within a comprehensive framework that provides a more accurate diagnosis of language-based learning difficulties?

Two related questions arise:

- What tools has each discipline contributed to the understanding and diagnosis of these difficulties?
- How can the language network serve as an organizing framework that integrates the linguistic hypothesis with neurological evidence and speech-therapy assessment into a unified process?

Building on this, the article aims to achieve two main objectives:

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1. To critically review recent studies in neurolinguistics, neurology, and speech therapy, and the tools they offer for diagnosing learning difficulties.

2. To propose an integrative network model in which diagnosis progresses through stages: starting with a neurolinguistic hypothesis, refined medically, tested through speech-therapy assessment, and finally translated into an educational decision in the early grades.

### **1. Neurolinguistics: Language as a Brain Network**

Neurolinguistics is defined as an interdisciplinary field that studies the relationship between language and the central nervous system, with a focus on the brain mechanisms responsible for speech production and comprehension<sup>1</sup>. Language is not merely a formal system of rules and structures; rather, it is a complex neurocognitive activity that requires an integrative approach. Any scientific account of language remains incomplete without linking it to the brain and the higher cognitive functions that support it. This perspective has opened new avenues for researchers to gain deeper insights into learning difficulties across different contexts, taking the language network as a theoretical framework.

The incorporation of neuroscientific techniques into the study of language represents a decisive turning point, as these tools have been applied across diverse research contexts and have established a new empirical foundation for testing linguistic hypotheses in practice. Electroencephalography (EEG) has made it possible to track neural responses in real time through precise temporal markers, such as N400, associated with semantic processing; P600, linked to syntactic structure; and MMN, which reveals the brain's sensitivity to phonological distinctions<sup>2</sup>. Functional magnetic resonance imaging (fMRI) has provided highly accurate spatial maps for identifying regions responsible for comprehension and syntactic processing. Diffusion tensor imaging (DTI) has enabled the tracing of white matter integrity between frontal and temporal areas, particularly the arcuate fasciculus, which plays a central role in linking sound and writing<sup>3</sup>. The importance of these tools lies in their capacity to bridge theoretical perspectives with empirical evidence, thereby reinforcing the status of neurolinguistics as a well-established scientific field.

Building on this foundation, contemporary research has proposed distinct theoretical and empirical frameworks. Angela Friederici, director of the Max Planck Institute for Human Cognitive and Brain Sciences, introduced a dual-pathway model combining evidence from functional

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magnetic resonance imaging (fMRI), Diffusion tensor imaging (DTI), and electroencephalography (EEG), presented in her 2017 book *Language in Our Brain*. This model shows that language processing relies on a dorsal pathway responsible for phonological–syntactic integration, and a ventral pathway that supports semantic processing<sup>4</sup>.

The significance of this model lies in its ability to explain variations in reading difficulties: some children struggle to connect sound and print due to impairments in the dorsal pathway, while others read fluently but fail to comprehend because of deficits in the ventral pathway.

In the same context, Stanislas Dehaene, professor at the Collège de France, offered a broader perspective on what is known as “Neuroeducation” in his 2020<sup>5</sup> book *How We Learn*. Using neuroimaging techniques (fMRI and EEG), he demonstrated that the Visual Word Form Area (VWFA) in the occipito-temporal cortex is not pre-given but develops through reading acquisition, and that its weak activation is directly associated with dyslexia<sup>6</sup>. These findings show that the brain has remarkable plasticity and can be reshaped through appropriate educational interventions, making early diagnosis a key condition for overcoming such difficulties.

In a recent systematic review published in *Clinical Neurophysiology* (2020), Feng Guo and Hao Bi, drawing on electroencephalography (EEG) and event-related potentials (ERP), concluded that reduced MMN response is a consistent marker of developmental dyslexia, even in children who show no clear behavioral signs<sup>7</sup>. These findings indicate that EEG is not merely a research tool but also an early diagnostic method capable of distinguishing developmental difficulties from environmentally induced delays, thereby opening practical avenues for practitioners in education, speech therapy, and neurology.

Several studies have examined the generalizability of the language network. A recent study by Gabri Tuckute and her team at the Massachusetts Institute of Technology, published in *Neurobiology of Language* (2022), used individual-level functional magnetic resonance imaging (fMRI) on speakers of 45 languages across 12 language families. The results showed that the brain topography of the language network is relatively stable across languages, while still being sensitive to the specific linguistic structures of each system. In the same vein, an international study (2024) found that the processing of Arabic words reveals distinctive neural features that challenge existing neurocognitive models of reading<sup>8</sup>.

Consequently, the development of diagnostic protocols that account for the root-and-pattern system of Arabic remains essential to improving the accuracy of reading disorder diagnoses among Arabic-speaking learners.

Gregory Hickok, Professor of Cognitive Neuroscience at the University of California–Irvine, published a 2023 study in *Nature Reviews Neuroscience* that integrated findings from functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and brain lesion data. His analysis demonstrated that speech processing is not confined to the classical Broca’s and Wernicke’s areas, but instead relies on a broader network encompassing multiple frontal and temporal regions<sup>9</sup>. These results highlight that understanding language difficulties cannot be limited to localized brain foci; rather, it requires a comprehensive awareness of the brain’s network architecture as a whole. This perspective further reinforces interdisciplinary approaches in the study of language disorders.

This perspective reached its culmination with the work of Evelina Fedorenko, who in 2024 published an article entitled “The Language Network as a Natural Kind” in *Nature Reviews Neuroscience*. Drawing on evidence from functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and lesion studies, she demonstrated that the language network constitutes a distinct system within the brain, relatively independent from domain-general cognitive networks, while still capable of interacting with them depending on task demands<sup>10</sup>. This finding represents a paradigm shift, as it shows that language-learning difficulties often stem from specific impairments within components of the network, rather than from a generalized deficit in cognitive abilities.

Recent studies have also sought to approximate more naturalistic conditions. In a 2024 study conducted at Harvard University, Yusuke Tsuyoka and his team measured the responses of the language network while participants listened to natural narrative texts, using functional magnetic resonance imaging (fMRI). The findings revealed that this network tracks continuous discourse moment by moment, rather than only in the context of artificial experimental tasks<sup>11</sup>. This shift is significant, as it opens new avenues for designing diagnostic assessments that mirror actual classroom practices such as reading and storytelling, instead of being restricted to narrow laboratory protocols.

The overall conclusion of these works is that neurolinguistics, through its experimental tools and theoretical models, has provided a foundation for understanding and diagnosing language learning difficulties. These are no

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longer confined to classroom observations but have become phenomena that can be measured neurologically and explained scientifically. Yet, despite their importance, such studies remain insufficient on their own, as the mere availability of a given device or technique requires more precise clinical calibration to determine the trajectory of the impairment and to rule out confounding factors.

## **2. Neurology: From Identifying the Cause to Characterizing Language Impairment:**

Neurology constitutes a central pillar in addressing language-related learning difficulties, as it provides what is known as the biological reference framework. While pedagogical tools—such as classroom tests and direct observations—can reveal manifestations of deficits in reading, comprehension, or spelling performance, their value remains limited unless complemented by neurological assessment. Such assessment identifies the nature of the impairment, traces its temporal progression, and measures the severity of its consequences<sup>12</sup>. The importance of neurological examination lies in its ability to link behavioral data with biological indicators, thereby rendering diagnosis an integrated process that goes beyond educational observation alone and opens the way to more precise therapeutic approaches.

Modern neurological practice relies on an integrated set of structural and functional tools that allow physicians to approach language impairments from multiple perspectives. Structural magnetic resonance imaging (MRI) enables the detection of cortical and subcortical anatomical abnormalities, while diffusion tensor imaging (DTI) provides precise information on the integrity of white matter tracts—most notably the arcuate fasciculus linking frontal and temporal regions. At the functional level, functional MRI (fMRI) makes it possible to track brain activation patterns during linguistic tasks, highlighting the dynamic distribution of processing across different regions. In addition, fluorodeoxyglucose positron emission tomography (FDG-PET) helps monitor neural metabolism and detect hypometabolism in degenerative conditions, allowing for the diagnosis of early metabolic decline even before it appears in conventional structural MRI. Electroencephalography (EEG), meanwhile, retains a special role in the clinical context, not primarily to study linguistic components as in neurolinguistics, but rather to detect latent epileptic activity that can disrupt language performance without being a linguistic deficit per se<sup>13</sup>. Taken together, these tools contribute complementary perspectives that construct a

multidimensional picture of language disorders, rendering neurological diagnosis a precise and complex process.

Many contemporary studies have highlighted that redefining the nature of language impairment can only be achieved through precise medical assessment. In his seminal study on Primary Progressive Aphasia (PPA), Marsel Mesulam (2001) demonstrated that certain language disorders are not due to educational weakness or learning deficits, but may constitute the first sign of a degenerative disease affecting cortical regions specific to language<sup>14</sup>. Mesulam described adult patients who gradually lost the ability to retrieve words and construct sentences while relatively preserving other cognitive functions. These results represent a fundamental shift in the approach to language impairment, showing that it is not always understood as an isolated learning disorder, but may be part of a broader pathological process requiring careful medical follow-up and integrated intervention plans.

These findings confirm that neurological examination is not merely a complementary procedure, but a necessary condition for distinguishing between stable developmental impairments and progressive degenerative conditions. Such conditions require precise monitoring protocols using techniques like MRI or FDG-PET to track the dynamics of metabolic and functional decline<sup>15</sup>. Without this distinction, the risk of reducing impairment to a superficial educational problem remains, as the gradual loss of language abilities may be misinterpreted as a learning weakness, when in fact it is an early symptom of a degenerative disease requiring careful medical follow-up<sup>16</sup>. Consequently, the limitations of diagnostic tools not only obscure the true nature of the impairment but also negatively affect the appropriateness of therapeutic interventions, making the integration of neurological assessment indispensable for mapping language impairments accurately.

Conversely, pioneering studies have shown that developmental disorders such as dyslexia also have a neurological basis, yet remain modifiable through appropriate intervention. Sally and Bennett Shaywitz conducted a series of studies using functional magnetic resonance imaging (fMRI) with children diagnosed with dyslexia. The results revealed reduced activation in the left temporo-occipital regions responsible for linking print to sound. More importantly, this reduced activation began to diminish after the children underwent intensive reading training, demonstrating that the presence of a “neural core” of impairment does not preclude the brain’s capacity for neuroplastic reorganization through suitable educational

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intervention<sup>17</sup>. These findings reveal that brain plasticity is a decisive factor explaining how systematic training can mitigate the impact of developmental impairment despite its neurological roots.

Neurological examination has not only identified the locus of impairment but has also made it possible to reprogram the neural network through targeted instruction. Supporting this perspective, research on white matter structure has shown—using diffusion tensor imaging (DTI)—that reduced integrity of the arcuate fasciculus is directly associated with difficulties in phonological processing<sup>18</sup>. These findings indicate that reading is not an isolated function but rather the outcome of a complex interaction among specific neural pathways that can be strengthened through sustained training and appropriate intervention.

Angela Friederici expanded this perspective by proposing the dual-pathway model, an approach originally formulated in neurolinguistics but which gains added value when applied in medical practice<sup>19</sup>. This model enables clinicians to account for the diversity of reading difficulties: for some children, an inability to integrate sounds into words is attributed to dysfunction in the dorsal pathway linking auditory regions to frontal areas responsible for phonological programming. For others, weaknesses in semantic comprehension appear despite their ability to read mechanically, due to deficits in the ventral pathway connecting temporal regions with the ventral prefrontal cortex. This framework illustrates how integrating neurological data into clinical practice provides physicians and therapists with new opportunities for more precise diagnosis and deeper understanding of the variability in reading impairments.

In Arabic research, there is a pressing need to adapt global neurocognitive models to the specific features of the Arabic language in order to capture the nuances among children with reading difficulties. Some struggle with grapheme–phoneme conversion, while others fail in reading comprehension despite being fluent in oral reading. This underscores that such models are not ready-made formulas but rather flexible frameworks to be adjusted within diagnostic and therapeutic protocols jointly developed by physicians and speech–language therapists. This adaptation is grounded in the unique morphological structure of Arabic, based on the root–pattern principle: the root functions as the core semantic unit, while the pattern provides a morphological template adding phonological and syntactic dimensions. This system was described in Arabic structural linguistics and later formalized by McCarthy within the framework of non-linear morphology<sup>20</sup>. Neuroimaging studies indicate that this structural parallel is

instantiated in the brain through the dorsal pathway (phonological processing of patterns) and the ventral pathway (semantic processing of roots)<sup>21</sup>. Accordingly, Arabic represents an ideal case for testing hypotheses on functional distribution in neurolinguistics, granting it a distinctive position in the global debate on the relationship between morphological structure and neural networks.

Clinical studies have demonstrated that reading difficulties among Arabic-speaking children may manifest in two distinct forms: deficits in recognizing shared lexical roots, or impairments in processing morphological patterns that determine the grammatical function of words. Addressing such challenges requires specialized diagnostic protocols that move beyond conventional phonological assessments to incorporate dual tasks targeting both root and pattern processing<sup>22</sup>. In this regard, Arabic functions not merely as a particular linguistic system but as a global laboratory for investigating the neural instantiation of morphological structures and the distinctive profiles of reading impairment that emerge from them.

Recent neuroscientific research has demonstrated that language processing cannot be reduced to the classical foci of Broca and Wernicke, but is instead distributed across a broad network involving multiple frontal and temporal regions. Hickok (2023), drawing on fMRI, MEG, and lesion studies, showed that language is organized within an interconnected network reflecting complex dynamics that transcend localized specialization<sup>23</sup>. Similarly, Fedorenko and colleagues (2024) highlighted that linguistic functions are distributed across integrated subsystems, such that comprehension and production emerge from the cooperative activity of multiple network nodes rather than from isolated regions. This underscores the value of network-based approaches<sup>24</sup>, which allow for more precise diagnoses of learning difficulties and prevent the reduction of impairments to a single localized deficit.

This network-based perspective gains particular significance when applied to processing in Arabic, as it reveals that the root-and-pattern morphology cannot be accounted for within a unidimensional framework—whether phonological or semantic—but rather emerges from the continuous interaction of different components of the neural network. The dorsal pathway is engaged in representing the pattern structure with its phonological–morphological complexity, while the ventral pathway contributes to the processing of roots as carriers of semantic information. Consequently, any deficit in one of these pathways is directly reflected in a

specific disorder, manifesting either as difficulty in pattern processing or as impairment in recognizing shared roots.

Some Arabic studies have argued that the medical diagnosis of reading difficulties should be grounded in the network-based perspective, whereby reading disorders are not reduced to a single localized site, but rather understood as dysfunctions within an interconnected network whose manifestations vary according to the morpho-semantic structure of Arabic<sup>25</sup>. From this standpoint, Arabic becomes an ideal model for applying global network frameworks, as its root–pattern morphology provides a testing ground for the hypothesis that language is a distributed network function rather than a localized activity.

Cross-linguistic research in neurolinguistics has added a qualitative dimension to the debate on the relationship between language and neural architecture. Recent imaging studies using DTI and fMRI have shown that patterns of white-matter connectivity vary according to the linguistic system; clear differences have been observed in the connections between frontal and temporal lobes among healthy speakers of typologically distinct languages such as Arabic, Chinese, and English. These findings highlight the necessity of considering language-specific features in medical diagnosis, since diagnostic tools designed for European languages may fail to detect reading disorders in Arabic-speaking children, whose brains are shaped by a root–pattern morphological system rather than by linear letter sequencing<sup>26</sup>. Consequently, it becomes essential to develop diagnostic protocols tailored to the structural particularities of Arabic, as reading difficulties may stem either from deficits in processing shared roots or from impairments in handling morphological patterns—forms of impairment that cannot be fully captured by tests imported from other linguistic contexts. Thus, incorporating a cross-linguistic dimension into neurodiagnosis is not a secondary epistemic option but a scientific necessity, ensuring that foreign models are not uncritically imposed on a divergent linguistic reality, and allowing for a more accurate interpretation of reading difficulties in light of the interactive relationship between native language and neural organization.

The cumulative body of research shows that neurology provides the biological baseline for understanding language learning difficulties: it identifies the neural locus of impairment, distinguishes between stable developmental deficits and acquired or degenerative conditions, and excludes confounding factors such as hearing loss, latent epileptic activity, or comorbid attention disorders. In this way, it offers an indispensable

preliminary framework for mapping the course of the condition and defining its medical trajectory. However, it remains a necessary yet incomplete link, reaching its full value only when integrated with neurolinguistics, which provides the theoretical models for interpreting the affected structures, and with speech–language pathology.

### **3. Speech–Language Pathology: Performance Benchmark and Clinical Validation of the Hypothesis:**

Speech–Language Pathology represents the applied link within the interdisciplinary diagnostic framework, as it transfers the neuro–linguistic hypothesis from its theoretical level to a practical test within the classroom or the clinic. While neurolinguistics formulates its hypotheses based on fine-grained neural indicators, and neurology provides the causal map and delineates the temporal trajectory of the deficit, Speech–Language Pathology subjects these hypotheses to direct behavioral testing. In this way, it becomes possible to determine whether the presumed impairments are actually manifested in observable difficulties in reading, speech, or comprehension. This integrative role grants Speech–Language Pathology an enhanced scientific dimension: it is not merely a therapeutic practice, but a methodological tool for validating diagnostic hypotheses and supporting them with behavioral evidence.

Building on this role, the value of Speech–Language Pathology is no longer confined to therapy alone, but has expanded to include the development of standardized measurement tools capable of converting clinical impressions into quantitative data. A prominent example is the Therapy Outcome Measures (TOMs), introduced by Enderby and John in 2015, which is structured around four core dimensions: impairment, activity, participation, and well-being. Performance is rated on an ordinal scale from 0 to 5, with half-point increments. Professional bodies in the UK and across Europe have since adopted this tool as part of their standard practices. This evolution demonstrates that Speech–Language Pathology has moved beyond being a procedural field reliant solely on the clinician’s expertise, becoming instead an objective measurement framework through which diagnostic hypotheses can be confirmed or revised on a rigorous scientific basis.

With technological progress, this standardized trajectory has expanded to include digital tools supported by artificial intelligence. In 2021, Koutsoumpa and colleagues developed an interactive platform based on automated recording and analysis of children’s speech, designed to monitor

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accuracy and fluency while providing therapists with immediate feedback<sup>27</sup>. Virtual reality environments have also been employed in post-aphasia rehabilitation, allowing for the simulation of natural communication settings that are difficult to reproduce in a conventional clinic<sup>28</sup>. These applications demonstrate that the integration of technology not only enhances the effectiveness of speech–language pathology interventions but also broadens their scope toward more realistic experiences and more precise performance assessment.

A systematic review encompassing more than fifty randomized controlled trials demonstrated that speech–language therapy following stroke significantly improves functional communication, expressive language, and reading comprehension. The findings further indicated that the intensity of intervention is positively associated with the degree of improvement, highlighting that effectiveness depends not only on the type of therapeutic program but also on its regularity and continuity<sup>29</sup>. This body of experimental evidence underscores that, when implemented within carefully designed protocols, speech–language therapy constitutes a cornerstone in the restoration of linguistic functions and the enhancement of patients' quality of life.

In the field of developmental difficulties, a review by Barquero et al. (2014), along with more recent studies, showed that intensive speech–language therapy can reshape activation patterns in the left temporo–occipital regions, thereby indicating that its effectiveness extends beyond linguistic behavior to include the reorganization of neural networks themselves<sup>30</sup>. In the Arabic context, Mziane (2016) found that intensive reading training focused on difficult phonemes improved phonological performance among pupils with reading difficulties, provided that the sessions were designed according to precise linguistic hypotheses and their outcomes assessed through quantitative indicators<sup>31</sup>. Taken together, these findings demonstrate that the effectiveness of speech–language therapy does not lie solely in general interventions, but rather in programs grounded in explicit neurolinguistic principles.

Likewise, Snowling and Hulme (2020) demonstrated that interventions based on enhancing phonological awareness and reading recoding produce measurable improvements in the performance of children with dyslexia, particularly when phonological and semantic dimensions are combined<sup>32</sup>.

Numerous studies and field experiments have shown that the greatest value of speech-language pathology (orthophony) emerges when it is adapted to the specificities of the target language, as we previously indicated. In Arabic, the root-and-pattern morphological system requires that rehabilitation protocols be designed according to a morphological logic that differs fundamentally from the linear systems of European languages. Recent research has demonstrated that training children to exploit this system enhances word recognition speed and spelling accuracy, while also helping to distinguish difficulties of environmental origin from those rooted in neurobiological structures<sup>33</sup>. This highlights that the effectiveness of speech-language intervention in Arabic is contingent upon adopting a morpho-semantic approach that capitalizes on the structural specificities of the language.

Based on the above, it can be argued that orthophony represents the practical benchmark for testing the validity of protocols grounded in neurolinguistic hypotheses, as it determines whether a deficit can be remediated through training or is deeply rooted in neural structures. At the same time, however, it remains limited if isolated from other fields; on its own, it is insufficient to account for the origins of the deficit. Likewise, neurolinguistics and neurology remain incomplete unless supported by a behavioral benchmark that validates their hypotheses in practice.

#### **4- Towards an Integrative Network Model of Language Learning Difficulties:**

Following this research review, it becomes evident that contemporary scholarship in neurolinguistics, neurology, and speech-language pathology has established that each discipline contributes an indispensable perspective to the understanding of language learning difficulties. The central challenge, however, lies in moving beyond the mere accumulation of partial insights toward the development of a comprehensive diagnostic–therapeutic model capable of addressing complex cases encountered in both classrooms and specialized clinical settings. Reliance on linear approaches—which conceptualize the learner as progressing through a predetermined sequence of assessments before being directed to therapeutic intervention—remains insufficient, as such models presuppose a unidirectional trajectory and reduce the multiplicity of diagnostic and remedial possibilities. In contrast, empirical evidence underscores that these difficulties do not originate from a single, isolable factor; rather, they emerge from a multifaceted network of interactions among neurological processes, linguistic structures, and educational environments.

From this perspective, we propose an integrative network-based framework that restructures the relationship among the four principal actors—the teacher, the neurolinguist, the neurologist, and the speech-language pathologist—within a dynamic system that enables multidirectional transitions between diagnosis and intervention. Such a framework ensures more precise and context-sensitive responses to the specificities of each case.

The need for such integration emerges from the very first moment a teacher observes slow reading or weak comprehension. While this observation does not constitute a diagnosis, it serves as an early warning that opens the door for consultation with other specialists. The neurolinguist may then formulate a hypothesis concerning a deficit in phonological awareness or syntactic processing, supported by EEG measurements. The neurologist subsequently intervenes to rule out potential brain lesions or hidden epileptic activity. The case is then referred to the speech-language pathologist, who tests the hypothesis behaviorally and evaluates the impact of therapeutic intervention. Although this trajectory may appear linear in form, in practice it represents only one possible mode of collaboration. The network-based model is founded on flexibility: diagnostic processes can begin at any entry point and shift dynamically to another depending on the specificities of the case—ensuring responses that are both more precise and more faithful to the complexity of reality.

The network-based diagnosis of language learning difficulties begins with the “zero stage,” a critical step that rules out sensory or medical factors which may distort the initial reading of school performance. Even mild hearing loss, undetected visual impairment, or hidden epileptic activity can mimic developmental language disorders. At this stage, a simple audiological test may show that a child struggling with spelling is in fact affected by partial hearing loss, where improving auditory processing is required before any linguistic intervention. The zero stage thus serves as the first line of defense against incomplete diagnosis, ensuring that the subsequent pathway rests on precise and unambiguous foundations.

Once sensory and medical integrity is established, the teacher acts as the first point of observation. Rather than providing a diagnosis, the teacher records early warning signs—such as slow reading, frequent spelling errors, or weak comprehension. These classroom observations can decisively alter a child’s trajectory. For instance, a pupil may read fluently yet consistently fail comprehension questions; a superficial behavioral explanation might obscure an underlying linguistic deficit. The teacher thus serves as an early-

warning node within the network model, triggering timely multidisciplinary diagnosis.

Building on these classroom signals, the neurolinguist formulates a precise hypothesis about the locus of impairment—phonological, syntactic, semantic, or, in Arabic, root-and-pattern based. This hypothesis is tested through electrophysiological or imaging markers (e.g., MMN, N400, P600) or by assessing white-matter pathways with MRI. For instance, a child may read isolated words correctly but fail to integrate them into meaningful sentences, a pattern consistent with weakened P600 responses and supporting a syntactic deficit. The neurolinguist thus bridges classroom observation and neural evidence, transforming early signs into testable scientific hypotheses.

In the next stage, the neurologist undertakes causal verification, ruling out acquired or degenerative disorders and excluding medical confounds that might distort initial interpretations. This step is crucial in cases of sudden decline in reading fluency; what seems like a developmental deficit may, in fact, be temporal-lobe epileptic activity revealed by EEG. Without this test, the case might be misclassified as developmental and subjected to ineffective training. Thus, neurological examination acts as a safeguard within the network model, preventing confusion between medical and linguistic causes and guiding intervention toward the correct path.

Subsequently, speech-language pathology takes over, testing the validity of the hypothesis through standardized performance measures. Rapid improvement after brief sessions of phonological blending indicates a remediable environmental difficulty, whereas persistent weakness despite training, combined with stable EEG anomalies, points to a developmental disorder. In Arabic, root-pattern tasks may reveal that spelling errors stem not from poor phonological awareness but from deficits in processing morphological patterns that determine grammatical function. Thus, speech-language pathology goes beyond therapy to accurately differentiate deficit types and direct intervention toward more specialized programs, such as training in morphological processing.

In the final stage, the results are consolidated into an integrated educational-therapeutic plan. Environmental difficulties are managed with classroom support, while developmental disorders require long-term speech-language rehabilitation and neurological follow-up. Acquired or degenerative cases demand medical protocols with complementary educational measures. Diagnosis thus shifts from a linear process to a dynamic network, where neurological data, linguistic hypotheses, and

speech-language assessments converge into actionable decisions. This model ensures precise differentiation between remediable difficulties and deeper conditions, enabling more effective intervention in the early years of schooling.

For instance, a teacher may observe that a nine-year-old reads fluently but makes frequent spelling errors. In traditional models, the child would be referred directly to a speech-language therapist. The network approach, however, integrates a neurolinguistic hypothesis that such errors may reflect deficits in morphological representation rather than simple training gaps. This is tested through morphological awareness tasks, and if the child fails, EEG measures (e.g., N400) are used to detect possible semantic–syntactic processing deficits. Thus, diagnosis evolves from a mere behavioral observation into a networked interpretation linking linguistic performance with neural indicators.

In a different case, a child may show severe reading slowness initially attributed to a developmental deficit. Yet, the speech-language therapist notices recurrent pauses unexplained by phonological awareness. A neurologist then conducts a medical EEG, revealing temporal epileptic activity, making pharmacological treatment a prerequisite for effective therapy. This case illustrates how the absence of a network perspective could lead to misdiagnosis and years of ineffective training.

For example, two children may initially present with the same slowness in reading, yet closer examination reveals fundamentally different causes. The first child improves rapidly after a short training in phoneme blending, indicating an environmentally induced delay that is easily remediable. In contrast, the second child shows no response to training; an EEG reveals reduced MMN reflecting a phonological developmental deficit, while MRI findings remain anatomically normal. In the first case, intensive pedagogical support is sufficient, whereas in the second, a long-term plan focused on phonological awareness becomes indispensable.

These examples underscore that the strength of the network model lies in its ability to distinguish between cases that appear similar on the surface but are fundamentally different in nature and treatment trajectory, thereby reducing diagnostic errors and enhancing the effectiveness of interventions.

What we propose here is not merely a redistribution of roles among the teacher, the neurolinguist, the neurologist, and the speech therapist, but rather a vision in which each actor serves as a corrective to the others within a dynamic network. The teacher provides the initial signal, yet this signal only acquires meaning once it is linguistically interpreted, supported by

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neurological indicators, and tested behaviorally. The neurologist does not simply rule out acquired disorders, but may also open possibilities that reshape the therapeutic plan as a whole. Likewise, the speech therapist goes beyond rehabilitation, becoming a tool for testing neurolinguistic hypotheses. In this way, diagnosis becomes an integrative dialogue, accumulating rather than dispersing knowledge, enabling a shift from the mere coexistence of disciplines to their interconnection, and from linear sequencing to interactive flexibility.

### **Conclusion:**

This study has demonstrated that language learning difficulties cannot be adequately understood or effectively addressed through a one-dimensional diagnosis, as they emerge from a complex interaction of neural structures, medical determinants, and classroom contexts. The critical review revealed that genuine scientific value can only be achieved by integrating insights from these three domains within a comprehensive, network-based framework. The key findings can be summarized as follows:

- Neurolinguistics has provided precise electrophysiological and neuroimaging tools (MMN, N400, P600, fMRI, DTI) to capture and explain patterns of phonological, syntactic, semantic, and root-pattern morphological deficits.
- Neurology has provided the biological baseline, distinguishing between developmental deficits and acquired or degenerative conditions, while ruling out potential medical confounders.
- The specific features of the Arabic language—particularly its root-and-pattern system—have demonstrated that the direct transplantation of foreign protocols may lead to classificatory errors, whereas local adaptation allows for more accurate diagnosis and more effective therapeutic response.
- The proposed integrative network model unified the work of the teacher, the neurolinguist, the neurologist, and the speech-language pathologist within a dynamic dialogical framework, leading to a differentiated educational–therapeutic decision.
- The network-based proposal, supported by applied examples, consolidates the position of neurolinguistics as a genuine bridge between brain sciences, language, and therapeutic practice, while simultaneously opening avenues for future research more closely

aligned with the realities of Arabic classrooms and their morpho-semantic specificities.

- This conception consolidates the role of neurolinguistics as a bridge between brain sciences, language, and educational-therapeutic practice, while at the same time opening prospects for future research that tests the effectiveness of the model in diverse Arabic classroom contexts, thereby enabling the development of more precise and comprehensive protocols.

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