

Original article

Beyond Modular Localization: Neurobiology of the Developing Language Network and Additional-Language Learning in Middle Childhood

Manar Almabrouk Elosta 

Department of English Language, Faculty of Arts and Languages, University of Tripoli, Tripoli, Libya

Manar.Elosta@uot.edu.ly

Abstract

Contemporary neuroscience has moved from classical localisationist accounts of language towards models in which language emerges from interacting neural systems. This critical integrative review examines the developing language network during middle childhood, with particular attention to neuroplasticity, verbal working memory, phonological processing, speech perception, oral repetition, and additional-language learning. It also considers intensive oral memorisation, including Qur'anic memorisation, as a culturally situated learning experience involving repeated listening, recitation, serial retrieval, articulation, attention, and teacher-guided correction. The review does not assume that memorisation improves intelligence or additional-language proficiency; instead, it identifies cognitive and linguistic processes that can be examined empirically. Contemporary evidence indicates that language relies on interacting cortical, white-matter, subcortical, and cerebellar systems rather than an isolated language centre. During childhood, functional specialisation, connectivity, attention, memory, and language processing continue to develop. Additional language learning provides further evidence for experience-dependent plasticity, although outcomes vary with age, exposure, proficiency, instruction, and individual differences. The Arabic–English phonetic interface is considered cautiously, particularly stop-voicing and voice-onset-time patterns. The review emphasises that /p/ is not a native phonemic contrast in Modern Standard Arabic and is absent as a native phoneme in many Arabic varieties, rather than assuming it is absent from all Arabic dialects. The authors propose a Developmentally Informed Neuro-Language Framework (DINF) to connect neural development, cognitive-linguistic processing, cultural learning experience, and pedagogy. DINF is conceptual and requires empirical validation. The review concludes by proposing a research agenda for Libyan children that separates culturally situated learning experience from measurable cognitive, phonological, auditory, and additional-language outcomes.

Keywords: Neurobiology of Language; Developmental Neuroscience; Neuroplasticity; Verbal Working Memory.

Introduction

Language is a complex human capacity requiring the coordination of auditory perception, phonological analysis, lexical retrieval, semantic interpretation, syntactic processing, working memory, attention, motor planning, and social-pragmatic processes. Earlier neurological accounts frequently attempted to explain language through relatively discrete cortical locations, particularly Broca's and Wernicke's areas. Contemporary neuroscience has progressively shifted towards network-based accounts in which language depends on interacting cortical systems and their structural and functional connections [1–3]. The historical importance of localisation remains substantial. Broca's observations contributed decisively to the development of neurological theories of language. However, modern examination of the brains associated with Broca's original cases showed that the lesions were more extensive than the simplified representation of a small isolated "Broca's area" suggests [1]. Language therefore cannot be adequately explained by assigning a complex cognitive function to a single anatomical location.

This shift has direct relevance to developmental language education. A child's language system is not simply a smaller version of the adult system. Neural specialisation, structural connectivity, cognitive control, and linguistic knowledge continue to change throughout childhood and adolescence [4,6]. Middle childhood is consequently an important period for studying the interaction between developing neural systems and increasingly complex linguistic experience. Additional-language learning provides a particularly useful context for examining this interaction. Children remain responsive to linguistic experience, but neuroplasticity should not be interpreted as unlimited or uniform. Age interacts with quantity and quality of exposure, proficiency, instructional context, language use, and individual differences [12,13].

A culturally situated question arises from intensive oral memorisation practices. In many Libyan communities, children may encounter several simultaneous linguistic and educational experiences: Arabic in formal and social contexts, Modern Standard Arabic in school, English as an additional language, and Qur'anic recitation through mosque- or family-based instruction. Qur'anic learning may involve repeated listening, imitation, serial recall, articulation, teacher correction, and retrieval of increasingly long verbal sequences. The present review was partly motivated by the author's observations as a mother and educator of children exposed to these overlapping learning environments. These observations are not treated as research data and cannot establish causal relationships. They instead provided the practical starting point for a broader scientific question: Could specific cognitive-linguistic processes involved in intensive oral learning be meaningfully related to processes already known to participate in language development and additional-language learning?

The purpose of this review is therefore deliberately cautious. It does not attempt to demonstrate that Qur'anic memorisation produces superior intelligence, memory, pronunciation, or English proficiency. Instead, it examines the neurobiological and cognitive processes potentially involved and proposes a framework through which these relationships can be empirically tested in the Libyan context.

Methodology

Review design

This article adopts a critical integrative review design. This methodology was selected because the purpose is to synthesise findings across developmental neuroscience, psycholinguistics, phonetics, language acquisition, neuroplasticity, and educational neuroscience while developing a theoretically informed research agenda.

The article is not presented as a systematic review or meta-analysis. No pooled effect size is calculated, and no claim is made that the literature search meets the methodological requirements of a formal systematic review. The literature was organised around five interconnected domains: development and organisation of language networks; verbal working memory and attention; phonological and speech-processing mechanisms; neuroplasticity and additional-language learning; and culturally situated oral memorisation. The analysis emphasised the distinction between established findings, reasonable theoretical interpretations, and hypotheses requiring empirical testing.

Analytical principle

Evidence from bilingualism, language development, phonetic learning, and memory research was not treated as direct evidence that Qur'anic memorisation produces equivalent outcomes. Likewise, cultural practice was not treated as an experimental intervention. The central analytical principle was: shared cognitive processes do not establish shared outcomes or causal transfer. This distinction is essential for avoiding both overinterpretation of neuroscience and unsupported claims about culturally meaningful educational practices.

From Broca's area to distributed language networks

Historical localisation and its limitations

The association between speech production and the left inferior frontal cortex is historically linked to Paul Broca's nineteenth-century clinical observations. These observations were foundational to neurological language research. However, modern neuroimaging of Broca's historical cases indicates that the relevant lesions were considerably more extensive than the simplified textbook concept of a small isolated speech centre [1]. The contemporary view therefore retains localisation as one level of explanation while recognising that language depends on communication between multiple regions. White-matter pathways provide structural routes through which information can be integrated across regions involved in speech perception, phonological processing, lexical access, comprehension, and production [2–4]. This distinction is particularly important in developmental neuroscience. A developing language system changes not only through local maturation but also through the increasing coordination of distributed neural systems.

The dual-stream perspective

The dual-stream model of speech processing proposed by Hickok and Poeppel distinguishes interacting dorsal and ventral processing pathways [2]. In broad terms, the ventral pathway contributes to mapping speech signals onto meaning, whereas the dorsal pathway supports relationships between auditory speech representations and articulatory systems. These pathways should not be interpreted as two independent language systems. Speech comprehension and production require interaction among multiple neural processes. The value of the model lies in moving beyond a single-centre account of language. More recent work similarly identifies a functionally coherent language network within the broader organisation of the human brain [3]. This perspective is relevant to education because it discourages claims that a specific classroom activity selectively "trains" one named brain region.

Structural connectivity and childhood

Language development is also related to the maturation of structural connectivity. Recent developmental research involving children aged 5–7 years has identified associations between dorsal and ventral white-matter tracts and phonological and semantic language processing [6].

These findings support a developmental account in which increasingly sophisticated language behaviour reflects not only vocabulary growth and explicit knowledge but also changes in the coordination and efficiency of distributed neural systems.

The developing language brain in middle childhood

Prolonged and heterogeneous development

Neural development during childhood is prolonged and heterogeneous. Functional specialisation, structural connectivity, attentional control, and language-related processing continue to change across childhood and adolescence [4,6]. Chronological age therefore cannot be treated as a complete description of a child's neurocognitive state. Children of the same age may differ substantially in language exposure, literacy, educational experience, memory, attention, family environment, and opportunities for interaction.

This variability is particularly important for additional-language learning. A child exposed to English daily through school, media, and social interaction may have a substantially different developmental trajectory from a child whose English exposure is restricted to a few classroom hours each week.

Verbal working memory

Working memory supports the temporary maintenance and manipulation of information during ongoing cognitive activity. Its relevance to language is therefore considerable because linguistic comprehension and production frequently require learners to retain information while simultaneously processing new material [7].

Gathercole et al. demonstrated developmental changes in working-memory structure between four and fifteen years of age, with substantial increases in functional capacity across the school years [5]. This developmental trajectory is relevant to children's ability to repeat unfamiliar sequences, retain phonological information, follow complex instructions, and manipulate verbal material. In additional-language learning, working memory may be involved when learners maintain unfamiliar sound sequences, compare them with existing phonological representations, retrieve lexical information, or construct utterances while monitoring their own production [9]. Nevertheless, working memory should not be reduced to a simple predictor of language proficiency. It operates within a larger system involving language knowledge, attention, exposure, motivation, phonological experience, and instruction.

Attention and retrieval

Attention allows learners to select relevant linguistic information while resisting competing stimuli. Retrieval allows previously encountered information to become accessible during later comprehension and production. Repeated oral learning can therefore involve attention, encoding, maintenance, retrieval, monitoring, and articulatory execution. These are legitimate processes for investigation. What remains uncertain is whether particular forms of intensive oral practice produce measurable benefits outside the trained activity itself.

Culturally situated oral memorisation

Disaggregating the practice

Oral memorisation is not a single cognitive operation. A child engaged in intensive memorisation may:

- listen to a model;
- discriminate speech sounds;
- encode phonological sequences;
- repeat verbal material;
- maintain sequences in working memory;
- retrieve previously learned material;
- monitor pronunciation;
- receive corrective feedback; and
- progressively increase the length and complexity of reproduced material.

Calling this entire process simply "memory training" therefore oversimplifies the learning experience. Qur'anic memorisation is also socially and culturally embedded. Children may differ in age of initiation, duration of participation, teaching style, home support, frequency of practice, and degree of engagement. These differences make direct comparisons between "memorising" and "non-memorising" children potentially misleading.

What current evidence permits

The available literature includes studies examining relationships between Qur'anic memorisation and cognitive performance, but the evidence remains limited. For example, Slamet [8] reported a small study involving ten kindergarten children. The study is relevant as preliminary evidence but cannot establish that memorisation causes general cognitive improvement or transfer to foreign-language learning. The distinction between association and causation is particularly important. Children participating in intensive memorisation may simultaneously differ in educational environment, parental involvement, discipline, literacy practices, religious education, socioeconomic circumstances, and other factors. Consequently, claims that memorisation improves intelligence, working memory, or English proficiency require appropriately controlled and preferably longitudinal evidence.

From cultural practice to measurable components

A stronger scientific approach is to decompose intensive oral memorisation into distinct, measurable cognitive-linguistic processes rather than treating it as a single form of "memory training." The following table maps key components of intensive oral memorisation onto their potential cognitive-linguistic processes and corresponding measures. This approach allows culturally situated learning experiences to be examined empirically while avoiding assumptions about causality or cognitive transfer. This approach preserves the cultural meaning of the practice while making its cognitive components scientifically testable.

Table 1. Decomposition of Intensive Oral Memorisation into Testable Cognitive-Linguistic Components and Measures

Practice component	Potential cognitive-linguistic process	Possible measure
Repeated listening	Auditory attention and speech perception	Auditory discrimination
Recitation	Phonological encoding and production	Phonological production tasks
Serial recall	Verbal working memory	Digit/nonword span
Repetition	Encoding and retrieval	Controlled repetition
Teacher correction	Monitoring and feedback-based learning	Error-detection and correction tasks
Pronunciation practice	Speech-motor and phonetic learning	Acoustic analysis/VOT
Extended memorisation	Sequence maintenance	Serial recall measures

Oral repetition, recall, and additional-language learning

Repetition is common in language learning because unfamiliar phonological and lexical forms require repeated exposure before they become efficiently accessible. Working memory becomes particularly relevant when linguistic material exceeds the learner's immediate processing capacity. The learner must retain part of a sequence while processing subsequent elements. This may be especially demanding when the sequence contains unfamiliar phonological structures. Current work on working memory and second-language learning emphasises that memory contributes to multiple aspects of additional-language processing, including comprehension, production, vocabulary, and grammar [9].

However, repetition should not be equated with communicative language development. Meaningful language use requires comprehension, lexical access, grammatical knowledge, interaction, pragmatic interpretation, and spontaneous production. The scientifically appropriate question is therefore not whether memorisation "makes children better at English", but whether identifiable components of intensive oral practice are associated with specific measurable outcomes.

Recitation is not equivalent to language comprehension

Accurate reproduction and linguistic comprehension are distinct outcomes. A child may reproduce a sequence of sounds accurately without necessarily understanding its semantic, syntactic, or pragmatic content. Recitation may therefore provide evidence of successful encoding, retrieval, sequencing, and articulation, but it does not independently demonstrate comprehension. This distinction is important when considering additional-language education. A learner may reproduce an English sentence accurately while still having limited understanding of its meaning or difficulty using the sentence spontaneously in an appropriate communicative context. Language comprehension involves mapping auditory input onto lexical, semantic, and syntactic representations. Production additionally requires conceptualisation, lexical retrieval, grammatical encoding, phonological encoding, and motor execution. Future studies should therefore use multiple outcome measures rather than a single global measure of "language ability."

The Arabic–English phonetic interface

Phonological transfer

Learners do not approach an additional language with an empty phonological system. Previous linguistic experience shapes how unfamiliar speech sounds and timing patterns are perceived and produced. Arabic varieties differ from one another, and claims about "Arabic" phonology should therefore be made cautiously. In particular, /p/ should not be described as absent from all Arabic dialects. A more defensible formulation is that /p/ is not a native phonemic contrast in Modern Standard Arabic and is absent as a native phoneme from many Arabic varieties, while its occurrence may arise in particular dialects, loanwords, or contact settings.

Recent Arabic–English research provides a useful illustration of cross-linguistic differences without justifying generalisation to all Arabic-speaking populations. Studies involving Jordanian Arabic learners have examined English /p/ and /b/ as well as differences in stop-voicing organisation [10,11]. For Libyan learners, these findings should be treated as comparative evidence rather than direct evidence about Libyan Arabic. Research specifically involving Libyan Arabic speakers remains necessary.

Voice onset time

Voice onset time (VOT) refers to the temporal interval between the release of a stop consonant and the onset of vocal-fold vibration. Languages differ in how stop categories are distributed along this temporal dimension. Recent research involving Arabic L1 learners of English and Spanish found evidence of cross-language interaction and phonetic plasticity in VOT patterns [10]. A related study of Arabic L1 learners of English reported that proficiency, phonological context, and distributional control were associated with English stop-voicing performance [11]. These findings are relevant to pronunciation teaching because they show that additional-language phonetic learning involves adaptation to language-specific distributions. They do not demonstrate that oral memorisation improves VOT control.

Why articulatory practice does not automatically transfer

Intensive oral practice may increase familiarity with articulatory sequences, but articulatory experience in one linguistic system does not automatically establish the phonetic categories required by another language. For this reason, pronunciation teaching should integrate auditory discrimination with production. Repetition can be useful, but learners also need opportunities to hear and distinguish contrasts that may not function in the same way in their first language.

Neuroplasticity and additional-language learning

Neuroplasticity refers broadly to the capacity of neural systems to change in response to experience. Additional-language learning provides an important example of experience-dependent adaptation [12]. Li et al. reviewed evidence for anatomical changes associated with second-language learning, including findings concerning grey- and white-matter organisation [12]. Such evidence supports the general principle that sustained linguistic experience can interact with neural development. However, plasticity should not be interpreted as a guarantee of equal learning outcomes at all ages. Birdsong emphasised the interaction among plasticity, variability, age, proficiency, exposure, language use, context, and individual differences [13]. Middle childhood may therefore be an important developmental period without constituting a universal or "magical" window in which successful additional-language learning is guaranteed.

The basal ganglia and cerebellum

Language processing is not confined to the cerebral cortex. Subcortical and cerebellar systems have been implicated in aspects of language processing, sequencing, timing, learning, and coordination. Booth et al. reported connectivity involving the cerebellum, basal ganglia, and cortical regions implicated in phonological processing [14]. More recent work has encouraged the incorporation of the cerebellum into broader frameworks of language processing [15]. However, the existence of neural involvement does not establish that a specific learning activity selectively strengthens a particular structure. Claims that memorisation "develops the cerebellum" or "trains the basal ganglia" would therefore exceed the available evidence.

Neuroplasticity is not a pedagogical prescription

Neuroscience can inform education, but neuroscientific findings cannot automatically be converted into classroom prescriptions. Howard-Jones described the persistence of neuromyths and the risks involved when complex neuroscientific findings are transformed into simplified educational claims [16]. Reviews of neuromyths similarly demonstrate the persistence of unsupported assumptions about learning and the brain [17].

The present review therefore rejects the following claims: repeated memorisation automatically increases intelligence; early language learning guarantees superior proficiency; one activity selectively "activates" a language area; recitation directly strengthens a particular brain structure; and neuroplasticity means that any linguistic experience will produce beneficial neural change. A scientifically responsible position is more modest: particular learning experiences may engage cognitive processes relevant to language learning, and these relationships can be tested empirically.

Teacher neuro-literacy

Teachers do not need to become neuroscientists. They do, however, benefit from understanding the limits of neuroscientific evidence.

Teacher neuro-literacy should include four principles:

- Language is supported by interacting neural systems rather than one isolated language centre.
- Children's cognitive and linguistic capacities develop over time.
- Working memory and attention influence language learning but do not determine it.
- Culturally meaningful learning practices should not be converted into claims of cognitive superiority without appropriate evidence.

Such knowledge can help teachers resist neuromyths while encouraging developmentally informed assessment and instruction.

Developmentally informed neuro-language framework

The Developmentally Informed Neuro-Language Framework (DINF) is proposed as a conceptual model for integrating developmental neuroscience, cognitive-linguistic processing, cultural learning experience, and educational practice. DINF consists of four interconnected dimensions.

Neural development

This dimension includes functional specialisation, structural connectivity, cortical development, white-matter organisation, and the interaction of cortical, subcortical, and cerebellar systems.

Cognitive-linguistic processing

This includes attention, verbal working memory, phonological processing, auditory perception, retrieval, lexical access, and language production.

Cultural and learning experience

This dimension includes oral repetition, memorisation, literacy, classroom instruction, family practices, religious education, and language-use environments.

Pedagogical implementation

This includes developmentally appropriate instruction, corrective feedback, phonological training, meaningful communication, and assessment of actual educational outcomes.

The relationships presented in Table 2 are conceptual and reciprocal rather than unidirectional. In particular, the inclusion of cultural learning experience does not imply that memorisation or recitation produces specific cognitive or neural changes. Instead, DINF provides a structured basis for examining how developmental, cognitive-linguistic, experiential, and pedagogical factors may interact and how these relationships can be tested using behavioural, linguistic, and developmental measures.

Table 2. Developmentally Informed Neuro-Language Framework (DINF)

Domain	Core process	Potential relevance to additional-language learning	Appropriate research focus
Neural development	Functional specialisation and structural connectivity	Increasing integration of language processing	Developmental and behavioural measures
Auditory processing	Speech perception and discrimination	Identification of unfamiliar phonological contrasts	Auditory discrimination
Phonological processing	Encoding and manipulation of sound sequences	Learning unfamiliar sound patterns	Phonological awareness and nonword-repetition tasks
Verbal working memory	Temporary maintenance and retrieval	Retaining unfamiliar linguistic sequences	Standardised working-memory measures
Attention	Selective processing and monitoring	Focusing on relevant linguistic input	Attention and language-processing tasks
Oral repetition	Repeated perception and production	Reinforcement of phonological and lexical representations	Controlled repetition and longitudinal measures
Cultural learning experience	Memorisation, recitation, teacher correction	Potentially relevant to repeated auditory-verbal practice	Documented exposure rather than assumed intervention effects
Additional-language exposure	Quantity, quality, and duration of input	Development of language-specific representations	Detailed exposure histories
Pedagogical implementation	Instruction, feedback, meaningful communication	Translation of cognitive knowledge into classroom practice	Behavioural and educational outcomes
Empirical validation	Integration of developmental, behavioural, and linguistic evidence	Testing proposed relationships without assuming causation	Longitudinal and appropriately controlled designs

Implications for childhood English education

The review supports several cautious educational implications. First, early English instruction should provide substantial opportunities for listening and phonological discrimination. Learners need exposure to contrasts that may not be organised identically in their first-language phonological system. Second, oral repetition can be useful when embedded in meaningful language activity. Repetition should not become synonymous with language learning. Children also require comprehension, vocabulary development, grammar, interaction, and spontaneous production. Third, teachers should distinguish memorisation from communicative competence. Accurate reproduction of a sentence does not necessarily demonstrate flexible understanding or spontaneous use. Fourth, pronunciation teaching can integrate auditory discrimination with articulatory feedback. This is particularly important when the first and additional languages organise speech contrasts differently. Finally, culturally familiar learning practices can be incorporated respectfully without attributing unsupported cognitive benefits to them.

Clinical and applied relevance

A network-based perspective has potential relevance beyond classroom instruction. Difficulties in language development may involve multiple interacting processes, including speech perception, phonological processing, working memory, attention, lexical access, and language production. Consequently, a network perspective supports multidimensional assessment rather than attributing every language difficulty to a single "language area."

The present review is not a clinical study and does not propose diagnostic criteria or therapeutic interventions. Any clinical application of DINF would require direct empirical research involving appropriate clinical populations and validated measures.

Future empirical research in Libya

The principal practical contribution of this review is the identification of a research agenda for the Libyan context. A future empirical study could examine children approximately 7–10 years of age and investigate whether documented experience with intensive oral memorisation is associated with specific cognitive-linguistic outcomes. Participation should be conceptualised as a continuous or carefully documented exposure rather than as a simplistic binary category.

Limitations

This review has several limitations, but each identifies a direction for future work. First, the article is a critical integrative review rather than a systematic review or meta-analysis. Future research can address this limitation through a preregistered systematic review with explicit search strategies, inclusion criteria, and quantitative synthesis where appropriate. Second, much of the neurobiological and phonetic evidence comes from populations outside Libya. This limits direct generalisation. The appropriate solution is locally conducted research involving Libyan children and, where relevant, speakers of specific Libyan Arabic varieties. Third, Arabic is linguistically diverse. Findings from Jordanian Arabic should therefore not be automatically transferred to Libyan Arabic. Future studies should document the participants' Arabic variety and measure the relevant phonetic contrasts directly. Fourth, evidence connecting Qur'anic memorisation specifically to cognitive transfer remains limited. This should be addressed through longitudinal, adequately powered studies using multiple outcome measures rather than global claims about intelligence. Finally, DINF is a conceptual framework rather than an empirically validated model. Its value should therefore be judged by its ability to generate testable hypotheses rather than by treating it as an established neuroeducational theory.

CONCLUSION

Contemporary neuroscience has moved substantially beyond the idea that language resides in a single cortical location. Language emerges through the interaction of distributed cortical, white-matter, subcortical, and cerebellar systems that develop and reorganise through maturation and experience. Middle childhood represents an important stage within this developmental trajectory. Children continue to develop language-related neural connectivity, working memory, attention, phonological processing, and increasingly specialised linguistic representations. Within this broader context, intensive oral memorisation represents an interesting but unresolved research question. Practices involving repeated listening, recitation, retrieval, articulation, and teacher-guided correction engage processes that are relevant to language learning. This observation does not establish that memorisation produces superior intelligence, working memory, pronunciation, or additional-language proficiency. The present review therefore proposes a more cautious scientific approach. Rather than asking whether a culturally meaningful practice is inherently beneficial or detrimental, researchers should identify its component processes and examine their relationships with measurable outcomes.

Dedication

This work is dedicated with gratitude to Professor Abdulsalam Tantani, Professor of Psycholinguistics at the Libyan Academy, Janzour, whose academic guidance during my doctoral studies encouraged me to engage more deeply with neurolinguistics and psycholinguistics. His teaching and scholarly influence contributed to the development of the questions that underlie this review and encouraged me to examine language learning not only as an educational process, but also as a complex interaction between cognition, language, development, and the human brain.

Conflict of interest

The author declares no competing interests.

References

1. Dronkers NF, Plaisant O, Iba-Zizen MT, Cabanis EA. Paul Broca's historic cases: high resolution MR imaging of the brains of Leborgne and Lelong. *Brain*. 2007;130(5):1432–1441. doi:10.1093/brain/awm042.
2. Hickok G, Poeppel D. The cortical organization of speech processing. *Nat Rev Neurosci*. 2007;8(5):393–402. doi:10.1038/nrn2113.
3. Fedorenko E, Ivanova AA, Regev TI. The language network as a natural kind within the broader landscape of the human brain. *Nat Rev Neurosci*. 2024;25(5):289–312. doi:10.1038/s41583-024-00802-4.
4. Skeide MA, Friederici AD. The ontogeny of the cortical language network. *Nat Rev Neurosci*. 2016;17(5):323–332. doi:10.1038/nrn.2016.23.
5. Gathercole SE, Pickering SJ, Ambridge B, Wearing H. The structure of working memory from 4 to 15 years of age. *Dev Psychol*. 2004;40(2):177–190. doi:10.1037/0012-1649.40.2.177.
6. Mathur A, Zheng H, Wang Y, Mues M, Booth JR. The association of dorsal and ventral white matter tracts with phonological and semantic processing of language in 5- to 7-year-old children. *Dev Cogn Neurosci*. 2026;77:101662. doi:10.1016/j.dcn.2025.101662.

7. Baddeley A. Working memory and language: an overview. *J Commun Disord.* 2003;36(3):189–208. doi:10.1016/S0021-9924(03)00019-4.
8. Slamet S. The effect of memorizing Quran on the children cognitive intelligence. *Humanit Soc Sci Rev.* 2019;7(3):571–575. doi:10.18510/hssr.2019.7384.
9. Sagarra N. Working Memory in Second Language Research. In: Chapelle CA, Trenkic D, Bruin A, eds. *The Encyclopedia of Applied Linguistics.* Wiley; 2026. doi:10.1002/9781405198431.wbeal1286.pub2.
10. Aldamen H, Al-Deaibes M, Alsharefeen R, Almashour M. Voice onset time in Arabic L1 learners of English and Spanish: evidence for stability, interaction, and phonetic drift in multilingual speech. *Front Lang Sci.* 2026;5:1806365. doi:10.3389/flang.2026.1806365.
11. Aldamen H, Al-Deaibes M, Alsharefeen R, Almashour M. Proficiency, phonological context, and distributional control in Arabic L1 learners' English stop voicing. *Front Lang Sci.* 2026;5:1827262. doi:10.3389/flang.2026.1827262.
12. Li P, Legault J, Litcofsky KA. Neuroplasticity as a function of second language learning: anatomical changes in the human brain. *Cortex.* 2014;58:301–324. doi:10.1016/j.cortex.2014.05.001.
13. Birdsong D. Plasticity, variability and age in second language acquisition and bilingualism. *Front Psychol.* 2018;9:81. doi:10.3389/fpsyg.2018.00081.
14. Booth JR, Wood L, Lu D, Houk JC, Bitan T. The role of the basal ganglia and cerebellum in language processing. *Brain Res.* 2007;1133(1):136–144. doi:10.1016/j.brainres.2006.11.074.
15. LeBel A, D'Mello AM. A seat at the (language) table: incorporating the cerebellum into frameworks for language processing. *Curr Opin Behav Sci.* 2023;53:101310. doi:10.1016/j.cobeha.2023.101310.
16. Howard-Jones PA. Neuroscience and education: myths and messages. *Nat Rev Neurosci.* 2014;15(12):817–824. doi:10.1038/nrn3817.
17. Grospietsch F, Lins I. Review on the prevalence and persistence of neuromyths in education—where we stand and what is still needed. *Front Educ.* 2021;6:665752. doi:10.3389/feduc.2021.665752.