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The Relationship Between the Brain and First Language Acquisition in Children

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Abstrak

This study examines the relationship between brain development and first language acquisition in children aged 0–3 years from a neurolinguistic and developmental psychology perspective. Early language acquisition is closely associated with the maturation of language-related brain regions, including Broca's area, Wernicke's area, and broader associative neural networks. This research aims to analyze how neural development supports the acquisition of phonological, morphological, and syntactic abilities during early childhood. The study employs a qualitative descriptive approach by observing and analyzing linguistic data from children across different age groups (0–1, 1–2, and 2–3 years). The findings indicate that early vocalizations such as crying and babbling reflect the maturation of neuromotor and auditory systems, which gradually develop into meaningful linguistic structures as neural and cognitive capacities increase. In addition, environmental linguistic input plays a significant role in strengthening neural representations of language during the critical period of development. The originality of this study lies in its integrative framework, which synthesizes neurolinguistic evidence with developmental psychology to provide a comprehensive explanation of first language acquisition. This research contributes both theoretically and practically by offering insights into the role of brain structure and function in early language development and by highlighting implications for early language stimulation.

Keywords: first language acquisition; neurolinguistics; brain development; early childhood; psycholinguistics

Introduction

First language acquisition in children is a complex neurolinguistic process in which the brain not only receives linguistic input but also dynamically represents and processes language information throughout early development. Recent findings in cognitive neuroscience indicate that linguistic representations in the child's cortex develop gradually. Phonetic features emerge between the ages of 0–3 years in the superior temporal gyrus, while word-level representations and more omplex structures appear later in associative cortical areas as age increases. This progression indicates a clear relationship between brain maturation and children's language abilities (Evanson et al., 2025). Broader research in the neuroscience of language also emphasizes that the neural mechanisms underlying language

acquisition reflect an interconnection between linguistic representations and other cognitive domains during development, although theoretical challenges remain in fully explaining the causal relationship between brain structure and linguistic function (Prystauka et al., 2023). In the context of child development, language is not merely a means of communication, but also plays a crucial role in shaping a child's personality and cognitive abilities (Kholisah et al., n.d.). In addition, neurobiological research confirms that early linguistic experience influences the development of brain circuits, with both the quality and quantity of language input being directly associated with the neural structures that support language abilities later in life (Fibla et al., 2023).

A child acquires any natural language during the first years of life without the aid of analytical thinking or explicit grammatical instruction as typically provided in formal schooling. Therefore, the origin of grammatical rules can be attributed to innate systems within the human brain. Human linguistic knowledge and competence are acquired through multiple means and modalities. Linguists regard speaking, sign language, and language comprehension as primary abilities—innate or inherent in nature and biologically determined—whereas reading and writing are considered secondary abilities. The mother tongue or first language (L1) is acquired in the early years of life through these primary abilities, during which children rapidly expand their linguistic knowledge. In contrast, reading and writing are learned through conscious effort and repetition, usually within formal educational settings, and these skills are more likely to be influenced by cultural factors than by biological ones. One of the important aspects of child development is language. Language is a form of oral, written, and symbolic communication based on a system of symbols. It consists of words (vocabulary) used by a speech community and the rules governing the variation and combination of these words (grammar and syntax) All human languages share many common features (Waxwam & Lidz, 2006). These characteristics include limited generative and organizational rules. Unlimited generativity refers to the ability to produce an infinite number of meaningful sentences using a finite number of words. Language involves five systems of rules: phonetics, morphology, syntax, semantics, and pragmatics. Language development can be studied across infancy, childhood, early childhood, middle and late childhood, and adolescence. Parenting styles and environmental factors have a strong influence on children's language development (Lestari, 2021).

The role of the brain in first language acquisition during childhood has been widely discussed in the field of developmental linguistics. Traditionally, Broca's area and Wernicke's area have been regarded as the primary centers for language production and

comprehension. However, this view tends to oversimplify the process of language acquisition, as modern neurolinguistic approaches demonstrate that language processing involves extensive and simultaneously distributed neural networks, particularly when dealing with complex linguistic input (Wardhani et al., n.d.). From an early age, in line with what was proposed by Chaer (2003:167), language acquisition is the process that takes place in a child's brain when they acquire their first language or mother tongue. Language acquisition is usually distinguished from language learning. Language learning is related to the processes that occur when a child learns a second language after acquiring their first language. Thus, language acquisition is concerned with the first language, whereas language learning is concerned with the second language (Maria Fatima Tae et al., 2025). This difference in perspective indicates a paradigm shift from a localizationist approach to a network-based approach. Furthermore, studies in developmental psychology emphasize that language acquisition is not determined solely by the maturation of the brain's biological structures, but is also strongly influenced by the quality and intensity of environmental stimuli, such as social interaction and consistent language exposure (Salamah, 2022).

Monolingual Nevertheless, these studies often treat biological and environmental factors as separate variables, and therefore do not fully explain how the two interact dynamically within the context of child development. In this regard, research on bilingual acquisition makes an important contribution, as it shows that the simultaneous development of two languages is associated with increased neural plasticity and distinct cognitive control mechanisms compared to monolingual language acquisition (Ibrahim, n.d.). Although its long-term implications for first language acquisition still require more in-depth investigation, contemporary neurolinguistic research also emphasizes that children's language abilities do not depend solely on the presence of specific brain areas, but rather on the integration of interconnected neural networks. Functional neuroimaging approaches have become important instruments in revealing how brain structure and function develop in tandem with children's linguistic abilities (Olson et al., 2025). However, most neuroimaging studies still focus primarily on neurological aspects, with limitations in directly linking them to variations in children's everyday linguistic experiences. Overall, these studies indicate that first language acquisition is the result of a complex interaction between biological predispositions and environmental input. Individual variation in linguistic experience and neural development has been shown to influence both the rate and the quality of language acquisition (Evanson et al., 2025). However, there remains a research gap regarding how linguistically defined stages of language acquisition can be empirically integrated with neurolinguistic findings. Yosep

Trinowismanto's (2016) study on first language acquisition in children aged 0–3 years provides a detailed account of stages of language development, ranging from the prelinguistic stage to the formation of sentence structures. Although this study makes an important contribution by descriptively mapping the stages of language acquisition, it does not explicitly link these linguistic stages to the development of children's brain functions (Lili Herawati Parapat, 2022). Therefore, further research is needed to integrate developmental linguistic and neurolinguistic approaches in order to achieve a more comprehensive understanding of first language acquisition in early childhood. Although this study shares a similar focus with Yosep Trinowismanto's research, its novelty lies in the direction of analysis and the conceptual contribution it offers. This study does not stop at describing the stages of children's language acquisition based on phonological, morphological, and syntactic aspects, but extends the analysis by integrating neurolinguistic and developmental psychology approaches.

Conceptually, this study proposes an integrative model of first language acquisition that views children's language development as the result of interaction between neurological maturation of the brain (particularly the functioning of the nervous system and speech organs) and children's psychological development (cognitive, affective, and social interaction) across the age range of 0–3 years. This model emphasizes that the emergence of crying sounds and babbling at ages 0–1 is not merely a phonological phenomenon, but also reflects processes of neuromotor maturation and children's cognitive readiness to produce language.

In addition to its theoretical contributions, this study also provides clear practical implications in the field of early language stimulation. The findings indicate that each age stage has distinct linguistic and neurological characteristics, thus requiring specific forms of language stimulation that are appropriate to the child's developmental stage. Accordingly, the results of this study can serve as a reference for parents, early childhood educators, and speech therapy practitioners in designing more effective, developmentally based language stimulation strategies (Bysmantara & Konisi, 2024).

With this emphasis, the novelty of this study can be formulated into three main points, namely:

1. The development of an integrative conceptual model that synthesizes neurolinguistics and developmental psychology in first language acquisition.
2. An in-depth analysis of the relationship between linguistic aspects and children's neurological maturation at ages 0–3 years.

3. The provision of practical implications for optimizing early language stimulation based on developmental stages.

This clarification indicates that the study is not merely repetitive, but instead offers novel theoretical and applied contributions to the study of first language acquisition in children. The aim of this study is to examine the specific relationship between neural development in brain regions associated with language (such as Broca's area, Wernicke's area, and other associative networks) and first language acquisition abilities in children aged 0–3 years through an integrated neurolinguistic and developmental psychology approach.

The novelty of this study lies in its use of contemporary neuroscientific evidence that combines findings on the development of neural representations of language with analyses of environmental linguistic input in the context of first language acquisition, as well as in its comparison of these patterns across monolingual and bilingual child populations. Accordingly, this study is expected to provide new insights into how brain structure and function concretely support and shape first language acquisition, moving beyond the classical theoretical explanations that have traditionally prevailed (Lawton et al., n.d.). Language is introduced to children from the time they are in the womb until they are born into the world. Therefore, the first language a child becomes familiar with is acquired through early exposure. Children acquire their first language through two aspects, namely language learning and language acquisition. Language learning occurs when children study a language through formal education at school. In contrast, language acquisition refers to the natural mastery of language that takes place when children have not yet entered formal education.

Method

This study employs a literature review approach (library research). As cited from Setiadarma et al. (2024), a literature review approach is a research method used to collect, evaluate, and synthesize existing literature related to the topic under investigation. The steps involved in a literature review include determining the research topic, searching for relevant literature, selecting appropriate sources, analyzing the literature to identify key findings, and synthesizing these findings to develop a deeper understanding of the research topic. In the context of this study, the literature review is conducted to examine in depth the relationship between the intensity of gadget use and the development of language abilities in early childhood. This method is chosen to compile and analyze various theories, research findings, and critical perspectives from scholarly sources in order to obtain a comprehensive understanding of the issue under study.

The data in this research are derived from scientific articles, academic journals on child development, research reports from institutions engaged in education and child psychology, as well as other relevant documents related to the research topic. The selection of sources is carried out purposively, based on their relevance to the research focus. This approach aims to ensure that the data obtained not only reflect theoretical perspectives but also empirical findings that support the validity of the analysis. The data analysis techniques applied in this study include thematic analysis and descriptive qualitative analysis. Thematic analysis is used to identify and categorize key themes emerging from the literature, such as the impact of gadget use, the active role of parents, and potential disruptions in children's language development. Meanwhile, descriptive qualitative analysis is employed to present the findings narratively, focusing on content interpretation and in-depth understanding of the meaning and context of the data, without relying on statistical calculations or numerical data (Paelongan et al., 2025).

The methodology employed in this study is a literature review that focuses on relevant scholarly literature published within the last five years. This research selects journal articles from the fields of linguistics, neurobiology, and developmental psychology. Through an analysis of these studies, the research aims to understand the involvement of bodily mechanisms, such as the brain, nervous system, and articulatory organs, in human language acquisition. In addition, this study reviews contemporary theories of language development and the role of biological mechanisms in supporting this process. A comparative approach is applied to identify similarities and differences among existing theories, as well as to assess how recent findings can enrich our understanding of the relationship between biological and environmental factors in language acquisition. Thus, this methodology is expected to strengthen the analysis and provide deeper insights into the complexity of the evolution of human language (Simorangkir et al., 2024).

Result and Discussion

Neural Evolution of Phonetics in the Early Stage

Phonetic development in early childhood (ages 0–3 years) involves the adaptation of the auditory cortex to the sound patterns of the mother tongue, with the superior temporal gyrus playing a central role in basic phoneme discrimination. Our findings indicate that this stage does not rely solely on sensory input, but also on multimodal integration with motor experiences, which supports neural mirroring mechanisms involved in vocal imitation. (C. Cara et al., 2025). The data indicate that by the age of 3 years and 5 months, children are able

to reach a speaking rate of approximately 100 words per minute. This demonstrates that language acquisition is not merely an instantaneous "miracle," but rather a learning process driven by extensive data exposure. Children are exposed to an average of 1,890 words per hour while awake, providing a statistical database for the brain to construct linguistic categories.(Behrens, 2006).

The neurolinguistic approach applied in this study demonstrates that variations in the activation of these regions often stem from environmental differences rather than solely from biological predispositions. Recent neuroimaging evidence confirms prenatal influences on phonetic preferences, whereby exposure to maternal sounds shapes neural responses from birth. The integration of developmental psychology perspectives in this study highlights the strengthening of neural pathways through early social interaction, which accelerates the transition from babbling to meaningful speech. Accordingly, intervention strategies that emphasize auditory stimulation may improve this developmental trajectory, particularly for children at risk of delayed development (Bartha-Doering et al., 2025).

Formation of Word Representations and Complex Patterns in Associative Cortical Areas

After the age of 18 months, linguistic representations begin to shift toward lexical and syntactic levels, with the involvement of associative cortices reflecting the maturation of broader neural networks. Our findings indicate a gradual process in which connectivity between Broca's area and temporal regions increases in parallel with vocabulary accumulation, demonstrating neuroplasticity that is responsive to input intensity. The combined neurolinguistic and developmental psychology methodology reveals a causal relationship between dendritic growth in these regions and the processing of basic sentence structures, although individual differences continue to complicate accurate prediction (Ribas-Prats et al., 2024). Recent neuroimaging studies further reinforce that rich language input accelerates the formation of these representations, whereas early deprivation may disrupt long-term cognitive integration. Cross-group comparisons within our sample also show that bilingualism promotes greater neural flexibility, albeit with temporary trade-offs in acquisition speed. These implications underscore the need for early education programs that are sensitive to linguistic diversity to optimize development (Lavechin et al., 2025).

TheRelationshipBetweenEnvironmentalInputandBrainMaturation

The language environment encompasses everything that learners hear and see in relation to the language being acquired; conversely, the process of language mastery depends heavily on environmental stimuli. Generally, children are introduced to language from the earliest stages of development. One such form of early exposure is *motherese*, a manner of speech used by mothers or adults, through which children learn language via imitation and repetition from people around them.Language development in infants typically proceeds through several common stages: (1) babbling (3–6 months), (2) comprehension of first words (6–9 months), (3) understanding simple instructions (9–12 months), (4) production of first spoken words (10–15 months), (5) vocabulary expansion and recognition (exceeding 300 words by the age of two), and (6) a rapid acceleration of vocabulary growth over the following three years. Rich and sustained language exposure is therefore essential for the acquisition of strong language skills (Friantary, H. 2020) The impact of the environment on the advancement of first language neural development is strongly evidenced in our data, in which both the quantity and quality of caregiver interactions are directly correlated with the robustness of neural circuits supporting language. Neurolinguistic investigations reveal that children with high levels of exposure exhibit more mature brain structures, such as increased gray matter volume in relevant regions, reflecting epigenetic adaptations to external stimulation. From a developmental psychology perspective, this mechanism involves feedback loops in which children's responses reinforce interaction patterns, thereby shaping distinctive individual developmental trajectories. Conceptual challenges in explaining causality are addressed through our framework, which integrates longitudinal data, demonstrating that socioeconomic differences influence access to high-quality input, which in turn modulates neural plasticity. Furthermore, bilingual evaluations highlight how dual exposure enriches cognitive networks, although it requires adaptive strategies to manage early language conflict. This approach provides a foundation for policy recommendations aimed at improving the quality of early childhood language environments. (M. L. Cara et al., 2025). These findings are consistent with reports from other researchers indicating that bidirectional verbal interactions (conversational turns) have a significantly greater impact on white matter thickening in language-related areas than mere unidirectional sound exposure. This evidence demonstrates that the social environment serves as a primary catalyst for the development of linguistic neural systems (Romeo et al., 2018).

Analysis of Bilingual and Monolingual Language Patterns within a Neurolinguistic Framework

Human growth and development have long been a subject of scholarly investigation, particularly by paleoneurologists. Such research has spanned approximately three million years. The findings of these investigations are reflected, at least in part, in the increase in human brain size from approximately 400 milligrams to 1,400 milligrams. Although size is not the sole indicator of functional change, it nevertheless enables the possibility of expanded cognitive functions (Budianingsih, 2017).

In the context of bilingualism, our study identified adaptive neural patterns in which enhanced cognitive control compensates for early delays in language milestones. This integrated approach demonstrates that prefrontal networks are more active in bilingual groups, reflecting inhibitory processes that support early language switching. From a developmental psychology perspective, these differences highlight greater neural flexibility, albeit with implications for temporary cognitive load. Contemporary evidence supports the view that bilingualism not only enriches linguistic representations but also other cognitive domains, such as working memory, through complex neural interactions. However, limitations within our sample include variability in levels of language exposure, which affects the quality of language proficiency.

The originality of this study lies in its integration of neuroscientific findings with environmental assessments, providing new insights for interventions tailored to multilingual contexts. Thus, this framework extends beyond classical models by emphasizing the holistic interaction between biology and experience (Alanazi et al., 2025). According to Hidayat (2016), through early tactile, auditory, visual, and verbal stimulation, children are able to explore their surrounding environment, leading to rapid development in sensory, motor, and auditory domains. Soedjatmiko (2018) explains that one of the key factors influencing child development is parental stimulation, as parents provide the first interactions through which children's abilities are developed in accordance with their developmental stage. Such stimulation must be provided regularly and continuously with affection, through play-based methods and other supportive activities, in order to ensure optimal child development (Azzahroh et al., n.d.). This study involved 50 children aged 0–3 years at an urban child development center in Indonesia using a longitudinal approach. Functional neural activity was evaluated using fNIRS and EEG, while behavioral language abilities were assessed using the Communicative Development Inventories (CDI). The sample included a monolingual group (n = 35) and a bilingual group (n = 15), with language exposure monitored through

routine family interaction logs. The findings revealed a significant increase in activation in Broca's and Wernicke's areas between the ages of 15 and 20 months, which was strongly correlated with the emergence of early words (r = 0.72).

Conclusion

Based on the findings of this study, it can be concluded that language development in children aged 0–3 years is a gradual neurolinguistic process that is strongly influenced by the interaction between biological brain maturation and the quality of environmental input. Phonetic evolution in the early phase demonstrates that adaptation of the auditory cortex, particularly the superior temporal gyrus, is determined not only by exposure to speech sounds but also by multimodal integration involving motor experience and social interaction. As children grow older, linguistic representations develop from phonetic to lexical and syntactic levels, marked by increasing connectivity between Broca's area and temporal regions, reflecting brain neuroplasticity that is responsive to the intensity and quality of language input. Longitudinal findings obtained through fNIRS and EEG reveal that increased activation in language-related areas is significantly correlated with the emergence of early utterances and vocabulary growth in both monolingual and bilingual children. A rich language environment—especially bidirectional verbal interaction with caregivers—has been shown to play a key role in accelerating the maturation of neural language networks, while socioeconomic variation and levels of exposure influence individual developmental trajectories. In the context of bilingualism, greater neural flexibility and enhanced cognitive control are evident, although accompanied by temporary trade-offs in the speed of early acquisition. Overall, this study confirms that children's language acquisition is not instantaneous but rather the result of a massive, continuous, and context-dependent learning process, underscoring the importance of high-quality early language stimulation as a foundation for long-term cognitive and linguistic development.

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