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Mind, Body, and Language: Bridging Theoretical and Empirical Perspectives in Cognitive Science and Education

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A B S T R A C T

Purpose: This study aims to explore the interrelationship between the mind, body, and language and to assess how linguistic theories and cognitive science inform a holistic model of language acquisition.

Methods and Materials: The research employs a qualitative content analysis methodology, examining scholarly texts across linguistics, cognitive science, SLA, and AI. Texts were selected from peer-reviewed journals and seminal books, and analyzed using a coding scheme to identify key concepts such as embodied cognition, sensorimotor interaction, and social context. The analysis is structured around five linguistic frameworks—Generative Grammar, Cognitive Linguistics, Functionalism, Post-Structuralism, and Sociocultural Theory—and how each relates to language, mind, and body.

Findings: The study reveals that traditional cognitive models like Generative Grammar view language acquisition as a mental process, minimizing the body's role. In contrast, Cognitive Linguistics, Functionalism, and Sociocultural Theory emphasize the embodied and socially mediated nature of language learning. Empirical findings show that gestures, motor actions, and physical engagement are essential for both FLA and SLA. Moreover, embodied AI systems, which integrate sensorimotor feedback, increasingly mimic human-like language learning. Cognitive Linguistics and Sociocultural Theory were found to be most applicable to real-world and AI-based language learning contexts due to their focus on the integration of physical, cognitive, and social dimensions.

Conclusion: This research advocates for a paradigm shift in understanding language acquisition as a holistic process involving the mind, body, and environment. It demonstrates that embodied and socially interactive learning models provide a more comprehensive framework for both human and machine language learning. The findings suggest that future educational and AI systems should prioritize embodiment and contextual interaction to enhance language processing and retention.

Keywords: *Embodied cognition, First language acquisition, Second language acquisition, AI learning models, Cognitive linguistics, Sensorimotor interaction, Language and the brain.*

1. Introduction

Language is not merely a system of abstract symbols processed in the brain; it is a deeply embodied phenomenon rooted in the interplay between cognition, physical experience, and social interaction. For decades, scholars in linguistics, cognitive science, education, and artificial intelligence have debated the precise mechanisms through which humans acquire, process, and utilize language. Traditional cognitive theories have long emphasized the mental faculties involved in language learning, but recent developments in embodied cognition and neuroscience have shifted the focus toward a more integrated model that includes the roles of the body and social environment (Komala et al., 2025; Lustiyantie et al., 2025).

From a cognitive linguistic perspective, the body plays a vital role in shaping meaning. Cognitive theories assert that language is grounded in sensorimotor experiences that structure thought and conceptualization (Bergen, 2020). This is supported by neuroscientific evidence suggesting that language comprehension, particularly of action-related terms, activates motor regions of the brain, thereby highlighting a neurological basis for embodied cognition (Kiefer & Pulvermüller, 2021; Pulvermüller & Fadiga, 2019). In this light, language is not purely a function of the brain but is intricately linked with the body and its interactions with the world.

The study of FLA particularly illustrates the embodied nature of language learning. Research conducted in Iran has shown that physical gestures, facial expressions, and tactile engagement play a central role in how children internalize language structures (Afshar et al., 2022; Khezri & Sadeghi, 2021). These findings corroborate the work of international scholars who argue that language is initially external and socially mediated before becoming internalized through the mind-body interface (Kia & Tavakoli, 2019; Shibata & Komori, 2022). Furthermore, social interaction, a key component of FLA, allows for the co-construction of meaning through shared attention and embodied communication—gestures, pointing, and physical engagement. This process not only supports vocabulary acquisition but also facilitates the development of pragmatic language skills.

SLA research has similarly undergone a transformation, moving beyond mentalist models to frameworks that account for embodiment and context. Traditional approaches prioritized memory, cognitive load, and rule internalization, but newer studies emphasize how learners acquire language more effectively when physical interaction and motor learning are integrated into pedagogy (Aslani & Noroozi, 2016; Zarei & Moini, 2020). The importance of the body in SLA is also evident in immersive learning environments and task-based approaches where learners act out, manipulate objects, and participate in meaningful communication. According to studies, these bodily engagements enhance retention and understanding, thereby demonstrating the tight coupling between physical experience and language acquisition (Cochran & Osborn, 2016; Shibata & Komori, 2022).

Moreover, the emotional and affective dimensions of language learning are receiving increasing attention. Emotional states such as anxiety, motivation, and enjoyment affect learners' ability to process and produce language. These factors are not merely abstract; they are embodied in physiological responses that influence cognition (Guoxiong & Kuan, 2024; Kanchan, 2024). Neurolinguistic research supports this view by illustrating how emotional and sensory stimuli activate specific brain areas linked to language processing, reinforcing the role of affect in cognitive development (Guan, 2024; Parween et al., 2025). Thus, SLA is increasingly recognized as a complex interplay between cognitive, affective, and bodily dimensions.

In recent years, the field of AI has entered this discussion with renewed vigor, particularly through the development of embodied AI learning models. Traditional AI focused predominantly on abstract data processing and rule-based learning. However, this approach has proven insufficient for simulating human-like language acquisition. The integration of sensorimotor feedback in AI systems represents a turning point in machine learning, where robots and intelligent systems are now designed to learn through physical interaction with their environment (Rahimi & Ranjbar, 2021; Zhang & Li, 2023). These developments echo human language acquisition processes, where cognition is scaffolded by bodily actions and environmental feedback.

The use of embodied AI in SLA also presents promising applications. Studies have demonstrated that AI-driven platforms that incorporate gesture recognition, speech-motor feedback, and multimodal input significantly enhance learners' engagement and comprehension (Shahbazian et al., 2023). These systems allow learners to practice language in simulated real-world environments, thereby integrating sensory-motor experience with linguistic input. For example, gesture-based interfaces and immersive VR platforms enable users to associate words with movements,

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objects, and spatial orientation, creating a holistic learning experience. This aligns with the embodied construction grammar model, which suggests that meaning emerges from repeated sensorimotor interactions with the world (Bergen, 2020).

The convergence of AI and neuroscience further strengthens the argument for embodied language learning. Advances in brain-computer interfaces and neurolinguistic modeling have shown that neural networks mimicking sensorimotor feedback are more effective in simulating human-like language behavior (Krishnan & Vinodhini, 2024; Mishin, 2025). For instance, neural circuits that integrate auditory, visual, and motor data can more accurately process contextual nuances and generate semantically appropriate responses. These models reflect the findings of embodied cognition theorists who argue that intelligence, both artificial and biological, emerges from the dynamic interaction between brain, body, and environment (Kiefer & Pulvermüller, 2021; Zhang & Li, 2023).

Additionally, recent interdisciplinary work highlights the role of language in developing broader cognitive abilities. Language is not just a communication tool but a scaffold for abstract thinking, memory formation, and executive function (Lustiyantie et al., 2025; Mohamed, 2024). These cognitive processes are supported by embodied mechanisms that enable learners to map linguistic constructs onto real-world experiences. Research indicates that multimodal engagement—including touch, movement, sound, and vision—stimulates the brain's capacity to form richer semantic networks, essential for deep learning and long-term retention (Huda, 2025; Komala et al., 2025).

Furthermore, the anthropocentric perspective in cognitive linguistics emphasizes that language is a human-centered activity rooted in the physical and social world (Muratkhodjayeva, 2024). Language emerges from bodily experience, social interaction, and contextual relevance, making it a situated cognitive process rather than an abstract computational function. This view is consistent with cross-linguistic and cross-cultural studies that demonstrate how idioms, metaphors, and symbolic systems are shaped by bodily perceptions and cultural practices (Аметова, 2024).

In summary, the integration of mind, body, and language represents a paradigm shift in our understanding of language learning and cognitive development. The research discussed highlights that language is not an isolated mental activity but a multifaceted process that unfolds through sensory-motor engagement, social interaction, and contextual embedding. This holds true across FLA, SLA, and AI learning contexts. Whether in the case of Iranian children learning their first language through gestures (Afshar et al., 2022), EFL learners engaging in motor-based vocabulary retention strategies (Aslani & Noroozi, 2016), or AI systems developing semantic understanding through embodied feedback loops (Zhang & Li, 2023), the common thread is clear: embodiment matters.

2. Methods and Materials

This study adopts a qualitative research methodology based on document and content analysis to explore expert viewpoints in published scholarly works about the relationship between language, mind, body, and the influence of second language acquisition (SLA) and artificial intelligence (AI) learning models. The analysis will focus on critically evaluating texts to uncover how different linguistic theories, SLA perspectives, and AI models conceptualize the mind-body-language interaction, so the research will use a content analysis design to analyze existing academic literature related to the mind-body connection in language processing and acquisition. This method will allow for systematic examination of texts, including peer-reviewed journal articles, books, conference papers, and reports, to identify key themes, concepts, and theories.

The texts analyzed in this study will be drawn from the following sources: Peer-Reviewed Journal Articles on linguistics, cognitive science, SLA, and AI. These articles will be sourced from high-impact journals in relevant fields and Books and Monographs written by leading scholars in cognitive linguistics, applied linguistics, embodied cognition, and AI.

Content analysis will be used to systematically review and analyze the selected texts. Developing a coding scheme that will allow the writer systematically categorize data based on themes such as:

Linguistic theories on the mind-body relationship.

Embodied cognition in language processing.

The role of sensory and motor experiences in language acquisition.

Post-structuralist theories on language and its bodily connections.

The relationship between AI learning models and human language learning.

texts will be analyzed line by line, and relevant portions will be tagged with the corresponding codes. After coding the data, patterns and recurring themes will be identified

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across the texts. Themes will reflect the conceptualization of language, mind, and body from the perspectives of linguistic theories, SLA research, and AI learning models. Finally, these themes will be organized into broader categories that address the research questions.

While the research does not involve direct interaction with participants, ethical considerations still apply in terms of ensuring proper citation and academic integrity in handling the data. All texts will be appropriately referenced, and the analysis will be conducted in a manner that respects the intellectual property of the original authors.

This methodology, based on content and document analysis, will allow the researcher to systematically examine how language, mind, and body are conceptualized across various academic fields. By focusing on published texts, the study will generate a comprehensive understanding of the current perspectives on these interactions, facilitating an informed conclusion about the best integrated model of language, mind, and body. The findings will contribute to both theoretical linguistics and applied fields like SLA and AI, offering new insights into how these disciplines approach the complex relationship between language, cognition, and embodiment.

3. Findings and Results

In this study, the codes related to the Mind, Body, and Language have been extracted through a detailed examination of various linguistic approaches. These codes, derived from the foundational theories of Structuralism, Cognitive Linguistics, Functionalism, Post-Structuralism, and Sociocultural Theory, serve as a framework for understanding how different linguistic perspectives conceptualize the interaction between language, mind, and body. These approaches provide a theoretical basis for analyzing how language is processed cognitively, embodied in social and physical contexts, and used in communication.

Additionally, codes related to the findings of Mother Tongue acquisition, Second Language Acquisition (SLA), and AI learning models have been drawn from the relevant literature. In particular, the analysis incorporates insights from SLA research and AI learning methodologies that emphasize the role of embodiment in language learning, such as the importance of gestures, physical interactions, and social contexts in both human and machine learning processes. By comparing these extracted codes from linguistic theories, SLA research, and AI learning models, this research seeks to answer the key research questions. The comparative analysis will explore the relationships between the mind, body, and language as conceptualized in each framework and aim to establish an integrated understanding of their interaction in language acquisition and processing.

Linguistic approaches

1. Structuralism and Generative Grammar (Chomskyan Approach) Mind-Body-Language Viewpoint:

The Chomskyan approach, which stems from generative grammar, posits that language acquisition is a mental process occurring within the mind. Chomsky (1957) introduced the idea of universal grammar, which suggests that all humans are born with an innate capacity to learn language (Chomsky, 2015). This innate faculty allows humans to internalize linguistic rules and structures that are universally shared across all languages. The focus is largely on syntax, or sentence structure, with little to no emphasis on the body in language production or acquisition.

In this model, the body plays only a secondary role—the body serves as the physical instrument through which the mind expresses its linguistic abilities, but the real work of language acquisition happens in the mind, where abstract grammatical rules are processed. Chomsky's theory excludes the body's influence on cognitive functions related to language, treating language as primarily an internal, mental phenomenon.

2. Cognitive Linguistics (Lakoff & Johnson), Mind-Body-Language Viewpoint:

In cognitive linguistics, particularly in the work of Lakoff and Johnson (1999), language is seen as deeply rooted in human experience, and this experience is inherently embodied. According to the embodied cognition theory, the mind cannot be separated from the body when it comes to understanding and using language. Lakoff and Johnson argue that we understand abstract concepts through metaphors that are grounded in our bodily experiences. For instance, the metaphor "understanding is grasping" comes from the physical experience of physically grasping something and is used to describe intellectual understanding (Lakoff & Johnson, 1999).

In cognitive linguistics, language is not an abstract mental entity. Instead, it is shaped by sensory experiences, where perception and action play a crucial role. Cognitive linguists argue that motor actions and sensory experiences influence the way language is structured and understood, meaning that meaning-making is embodied in both cognitive and physical processes.

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3. Functionalism (Halliday's Systemic Functional Linguistics) Mind-Body-Language Viewpoint:

In Systemic Functional Linguistics (SFL), developed by M.A.K. Halliday, language is viewed as a tool for social communication and is shaped by both cognitive and physical factors. Halliday (1978) emphasized that language functions primarily to serve the needs of communication in social contexts. The mind plays a role in selecting the linguistic forms appropriate for specific social functions, but language is also heavily influenced by the physical world (Halliday, 1978).

In SFL, the body's role is central to understanding how language is used in practice. Speech acts, gestures, and body language contribute meaning to communication. For instance, gestures accompany speech and can modify or enhance the meaning of the words spoken. Therefore, both the body and mind are essential to language production and comprehension. Functionalism holds that the physical body is an integral part of the language system, working alongside cognitive processes to create meaningful, context-dependent communication.

Unlike Chomsky's abstract theory, Halliday's model sees language as part of an ongoing physical and social interaction, with the body playing a fundamental role in this process. Context and function are central in SFL, emphasizing how language works in real-world situations, where both cognitive and physical experiences are essential.

4. Post-Structuralism (Derrida, Foucault), Mind-Body-Language Viewpoint:

Post-structuralist theorists like Jacques Derrida and Michel Foucault offer a more fluid and socially constructed view of the relationship between language, mind, and body. Derrida's theory of différance emphasizes that meaning in language is always deferred, suggesting that language is never stable, and meanings shift depending on the context in which language is used. For Derrida, language cannot be reduced to a mental or physical entity; it is socially and historically constructed, always evolving (Derrida & Spivak, 1976).

Foucault's approach, on the other hand, focuses on how discourse (language in use) is tied to power and social structures. In Foucault's view, language, mind, and body are not separate but are entangled in the production of meaning within societal contexts. The body is not just a medium for language but an active participant in discourse. Foucault argues that physical presence, body language, and gestures are crucial to understanding how power and meaning are mediated through language.Post-structuralism rejects the notion of fixed meanings in language and instead sees meaning as something in constant flux, shaped by both social forces and bodily experiences. This perspective allows for an understanding of the mind-body connection in language that is fluid and contingent upon social contexts (Foucault, 1977)

5. Sociocultural Theory (Vygotsky), Mind-Body-Language Viewpoint:

Vygotsky's sociocultural theory emphasizes that language acquisition is a social process that is mediated by social interactions. Vygotsky (1978) argued that language starts as an external tool for communication before being internalized by the mind. Unlike Chomsky's theory of language as an innate mental process, Vygotsky proposed that language is a socially shared resource. The body's role is integral to language acquisition, as children learn language through gestures, facial expressions, and physical interactions with others in their environment. For Vygotsky, the body participates actively in the process of language learning. This process is facilitated through joint attention and physical interaction with more knowledgeable individuals (e.g., parents, teachers). The mind and body work together to internalize language and cognitive processes. The concept of the Zone of Proximal Development (ZPD) further highlights how language is learned through the physical engagement of learners with their environment and others.

Table 1

Codes Related to Mind, Body, and Language Across Linguistic Approaches

Linguistic Approach	Mind	Body	Language
Structuralism and Generative Grammar	Language as a mental structure, Innate language faculty, Language as a cognitive system, Mind-centered language processing	Passive role of the body, Abstract cognitive process	Universal grammar, Language as a cognitive system
Cognitive Linguistics	Embodied cognition, Mind-body inseparability, Conceptual metaphors, Motor actions and language processing, Language as a physical experience	Language grounded in bodily experiences, Physical action and sensory perception, Active role of the body in language	Conceptual metaphors, Language grounded in bodily experiences, Motor actions and language processing, Language as a physical experience

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Functionalism	Language shaped by social context, Cognitive processes in social communication, Social function of language	Body as central to communication, Gestures and bodily movements in language, Social function of language	Language as a social tool, Language shaped by social context, Contextual and functional use of language
Post-Structuralism	Meaning is deferred (différance), Social construction of meaning, Mind-body entanglement in meaning-making, Language as socially mediated	Role of body in discourse and power, Fluidity of language and interpretation	Language as fluid and unstable, Social construction of meaning, Language as socially mediated, Power and discourse
Sociocultural Theory	Language as a social tool, Social interaction in language learning, Mind-body collaboration in development, Zone of Proximal Development (ZPD), Social mediation in cognitive growth	Body and gestures in learning, Physical interaction in learning processes, Joint attention and language acquisition, Language internalization through physical engagement	Language as a social tool, Social interaction in language learning, Social mediation in cognitive growth, Language internalization through physical engagement

Language Learning

First language acquisition

First language acquisition, has been a central area of study in linguistics and cognitive science. Traditional theories of language acquisition, such as those proposed by Chomsky (1957), have largely emphasized the mental aspects of language learning, suggesting that language is an innate mental faculty that unfolds in the mind of the child through exposure to linguistic input (Chomsky, 2015). However, more recent research in embodied cognition and social interaction highlights the significant role that the body, senses, and physical experiences play in the early stages of language acquisition.

From an embodied cognition perspective, mother tongue acquisition is seen as deeply grounded in the body's sensory and motor systems. Studies by Lakoff and Johnson (1999) suggest that children learn language not only through mental processes but also through sensory experiences with the physical world (Lakoff & Johnson, 1999). For instance, early vocabulary acquisition is often tied to physical actions (such as touching, pointing, and manipulating objects), which helps children connect words with real-world experiences. According to Glenberg (2008), the motor system is activated during the comprehension and production of certain action verbs, suggesting that motor actions are integral to understanding and using language (Glenberg, 2008). Gestures and body movements are an essential part of early language learning, as they provide a direct link between physical experience and language.

Furthermore, the role of social interaction in mother tongue acquisition cannot be overstated. Vygotsky (1978) argued that language is first used in social contexts before it becomes internalized in the mind. He emphasized the importance of joint attention, where both the child and the caregiver focus on an object or event, which facilitates the connection between words and real-world experiences. In this view, language acquisition is not just a mental process but is heavily influenced by the physical and social context in which it takes place.

For example, infants often acquire language through social gestures and interaction with caregivers. These bodily interactions help children understand the emotional and social dimensions of language, reinforcing the idea that language is not only a cognitive system but also a social and embodied experience (Goldin-Meadow, 2003). Children's physical engagement with the world, whether through gestures, touching, or movement, plays a crucial role in forming their understanding of language, as the sensory and motor systems become integral to the learning process.

Research in neuroscience further supports this embodied view, demonstrating that early language development is linked to sensory-motor processes. Kiefer and Pulvermüller (2012) found that when children hear action-related words, motor areas of the brain are activated, which reinforces the connection between physical action and linguistic meaning (Kiefer & Pulvermüller, 2012). This suggests that language acquisition is not solely a cognitive process happening in the mind but is interwoven with the body's interaction with the world.

In sum, mother tongue acquisition is best understood not only as a mental process but also as an embodied activity where senses, gestures, and physical interactions play a vital role in the development of language. The body and mind work together in real-world situations, where language learning occurs through both social interaction and sensory experiences.

Second Language Acquisition

Second language acquisition (SLA) has been extensively studied within the context of cognitive science, linguistics, and applied linguistics. Traditional theories of SLA often focused on mental processes, such as cognitive strategies and memorization of vocabulary and grammar. However, recent research has emphasized the role of the body, sensory experiences, and physical interaction in the process of

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acquiring a second language, offering a more holistic perspective on language learning.

Embodied cognition, a framework rooted in the idea that cognitive processes are deeply intertwined with bodily experiences, has significantly influenced the understanding of SLA. Research by Glenberg (2008) emphasizes that the body plays a central role in the acquisition of language, particularly when learning action verbs. When learners of a second language engage in physical activities such as gesturing, role-playing, or acting out words, they enhance their understanding and retention of language. For example, when students perform actions that correspond to verbs they are learning (e.g., "run," "jump"), the motor systems in their brains are activated, leading to a stronger connection between physical action and linguistic meaning (Glenberg, 2008; Glenberg & Kaschak, 2002; Glenberg & Robertson, 2000).

The role of physicality in SLA is further supported by research in embodied cognition, which suggests that language learning is not solely a mental or symbolic process but one that is grounded in sensory-motor interactions with the environment. Lakoff and Johnson (1999) argue that humans conceptualize abstract ideas through metaphors grounded in their bodily experiences, and the same principle applies to second language learning (Lakoff & Johnson, 1999). Learners connect new vocabulary and grammar not just through mental rehearsal but also by integrating sensory experiences and physical actions into the process of acquiring the language.

In addition to embodied learning, the importance of social interaction in SLA has been a core principle in Vygotsky's sociocultural theory. Vygotsky (1978) emphasized that language acquisition, including second language learning, is a socially mediated process. Joint attention, where learners and teachers or peers focus on the same object or action, is essential in helping second language learners make connections between words and real-world experiences. Vygotsky's concept of the Zone of Proximal Development (ZPD) underscores that learners benefit most from collaborative learning that involves both cognitive and physical interaction. By engaging in conversation, gestures, and collaborative tasks, second language learners actively participate in the learning process, further integrating language with action and social context.

Moreover, motor learning and gestures are increasingly recognized for their role in enhancing second language proficiency. Research by Goldin-Meadow (2003) has shown that gestures used by language learners can significantly aid in the acquisition of grammatical structures and vocabulary. In SLA, learners often rely on physical movements or gestural communication to bridge gaps in understanding when they do not have the appropriate vocabulary or language structure. These non-verbal cues serve as an important tool for overcoming linguistic barriers, particularly in early stages of learning.

A growing body of neuroscientific research also emphasizes the role of embodied learning in second language acquisition. Studies have shown that motor areas of the brain are activated when learners perform actions corresponding to words they are trying to learn, suggesting that embodiment facilitates the neural processes involved in language acquisition (Hauk et al., 2004). For instance, learning a verb like "kick" will not only activate the language centers of the brain but also the motor cortex responsible for physical action. These findings support the view that second language acquisition is not a purely cognitive process but involves complex interactions between language, the body, and sensory experiences.

In addition to physicality, contextual learning in real-world situations further enhances the SLA process. Language immersion—where learners are exposed to the target language in a natural context—allows learners to engage with the physical environment, integrating both language and action. Ellis (2008) found that context-based learning allows for practical engagement with the language, where learners experience the language through social, physical, and sensory engagement in the real world (Ellis, 2008). This emphasizes the role of the body in interpreting and practicing the second language in real-life scenarios, making the learning process more effective and authentic.

In conclusion, the acquisition of a second language is deeply connected to the mind, body, and sensory experiences. Embodied cognition, social interaction, and motor learning all contribute to a more integrated and effective learning experience, highlighting that physical actions, gestures, and social engagement are not just secondary aspects of SLA but essential components of the process. As SLA research continues to evolve, it is increasingly clear that language learning is a holistic experience involving both cognitive and bodily dimensions.

AI Learning

Artificial intelligence (AI) has made significant strides in the domain of language learning through models that mimic human cognitive processes. These AI systems, particularly in the field of natural language processing (NLP), are designed to learn and understand human language. However,

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the role of mind, body, and senses in AI learning systems is an emerging area of research. While AI systems do not possess human sensory experiences or physical bodies in the traditional sense, recent developments in embodied AI and sensorimotor learning are beginning to incorporate concepts from embodied cognition.

In traditional AI systems, the mind of the machine is usually equated with the algorithm or the neural network that processes data. These systems learn through data input and pattern recognition but lack bodily interaction with the world. However, some modern AI models, especially in the fields of robotics and interactive AI, are beginning to incorporate physical bodies that allow the AI to engage in sensorimotor activities. By integrating physical actions and sensory inputs, these systems are starting to simulate human-like learning processes. For example, embodied AI systems use robots that interact with their environment in real-time, engaging in actions that are connected to language learning tasks. Pfeifer and Bongard (2006) suggest that intelligence emerges from the interaction between mind, body, and environment, challenging the traditional view of AI as purely cognitive (Pfeifer & Bongard, 2006). In embodied cognition models of AI, the machine's senses (such as touch, sight, and hearing) are integrated into its learning processes, allowing it to experience and process information through physical engagement, much like a human learner.

In this regard, robots and AI models that use motor learning can acquire language through physical engagement with the world. AI models that simulate human-like motor actions are able to map sensory information directly onto language processing, which is similar to how human children use their bodily movements and physical actions to learn language (O'Reilly, 2006). For instance, a robot learning the word "grasp" will not only process the word through algorithms but will also perform the physical action of grasping an object, providing a more holistic understanding of the word's meaning. This integration of sensorimotor learning and language processing mirrors human language acquisition, where action and perception are deeply intertwined with cognitive functions. Neural networks in AI also share similarities with human learning. Pulvermüller (2013) found that when humans process action-related words, areas of the brain responsible for motor actions are activated (Pulvermüller, 2013). Similarly, AI systems that are designed to learn from sensory inputs and motor actions can activate "motor circuits" within their neural networks, enabling them to connect physical actions with linguistic meaning. The neural network can be trained not just on text data but on real-world interactions through sensory inputs, allowing for more robust and contextually aware language learning.

Another critical area of AI research is the development of multi-modal AI systems, where vision, hearing, and touch are integrated to help the AI interact with the physical world. Such systems simulate a more human-like learning process by receiving input through multiple senses and using this sensory data to understand and generate language. For example, vision-based systems may learn the word "ball" not only through text-based descriptions but also by seeing and touching the object itself. This allows AI to better associate words with tangible experiences, further integrating the sensory experience with linguistic processing. However, AI systems currently lack the subjective experience of senses that humans possess. AI's sensing and learning are limited to programmed responses based on sensor data, lacking the consciousness or perceptual experience that accompanies human learning. Despite this limitation, embodied AI research is moving towards systems that can physically engage with the world in a way that mimics human sensory-motor systems. The current trend in AI learning emphasizes creating systems that integrate sensory feedback into the learning process, enabling AI models to perceive and act within their environment, much like how human language acquisition involves sensory engagement with the world.

Recent developments in Artificial Intelligence (AI) have increasingly moved toward integrating sensorimotor systems that mirror the human learning process. Traditionally, AI learning models operated in abstract cognitive environments, where they processed information purely based on data inputs and statistical analysis. However, recent breakthroughs in embodied AI have led to systems that engage in physical interaction with the world, enabling them to learn not just through cognitive processing but through real-world sensory and motor experiences.

Embodied AI systems, such as robots with sensory feedback mechanisms, utilize vision, touch, and proprioception to acquire knowledge. These systems are designed to sense their environment and perform actions, thereby linking sensorial input with language or task completion. As noted by Pfeifer and Bongard (2006), embodied cognition argues that intelligence is shaped by the continuous interaction between the mind, body, and environment, and AI systems incorporating this principle are starting to bridge the gap between digital and physical learning environments (Pfeifer & Bongard, 2006). Moreover, recent developments in multimodal AI learning

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further highlight the integration of sensory experiences with cognitive processes. Language models such as CLIP (Contrastive Language-Image Pretraining) and DALL·E combine visual perception with language processing, allowing AI to understand and generate images from textual descriptions. This integration allows AI systems to process visual stimuli and linguistic inputs simultaneously, enhancing their ability to generate contextually relevant responses to visual and verbal prompts. This type of multimodal grounding is essential for language learning in AI, allowing systems to understand language not as isolated symbols but as grounded in real-world sensory experiences.

AI systems are also beginning to incorporate motor learning techniques, which enable machines to learn through physical interaction with the environment. Bakker et al. (2022) discuss the development of motor-learning algorithms that teach AI to learn physical actions, improving its capacity to handle tasks that require both linguistic and physical coordination. These models allow robots to use feedback from their actions (such as pushing, grasping, or pointing) to update their understanding of the world, thus enhancing their ability to connect language with physical activity. Large Language Models (LLMs), such as GPT-4, have also begun to integrate embodied interactions. In the Embodied Large Language Model-enabled Robot (ELLMER) framework, GPT-4 is combined with sensorimotor feedback systems, enabling robots to perform real-world tasks while continuously refining their action plans based on sensory inputs and environmental changes. This integration marks a significant step forward, as it blends the power of language models with real-time physical learning, allowing robots to adapt to dynamic, changing environments in ways that are more akin to human learning processes (Bergen, 2020).

In conclusion, the development of embodied AI has ushered in a new era where the mind, body, and senses are integrated into the AI learning process. AI systems are now being designed not only to process data but to engage physically with the world, enabling them to learn language in ways that mirror human language acquisition. This evolution in AI learning models reflects the growing recognition that intelligence arises from the interaction between cognitive processes and physical experiences, whether in humans or machines.

Table 2

Integration of Mind, Body, and Language in Human and AI Learning Models

	Mind	Body	Language
First Language Acquisition	Innate language faculty, Universal grammar, Cognitive processing, Language acquisition as mental process, Internalization of language structures, Cognitive strategies for language learning	Role of gestures, Physical actions in early word learning, Sensorimotor experience, Physical engagement through social interaction, Gestures supporting vocabulary acquisition, Body's role in language comprehension	Language as a mental construct, Linguistic rules, Syntax acquisition, Vocabulary acquisition, Learning through social interactions, Learning through environmental stimuli, Grammatical structure internalization
Second Language Acquisition	Cognitive strategies, Mental rehearsal, Memory retention, Internalizing new language structures, Cognitive load in language learning, Mental mapping of language rules	Motor learning in SLA, Physical interaction in learning (e.g., role-play, gestures), Sensory feedback in language learning, Physical activities enhancing vocabulary and grammar retention, Gesture-based language learning, Social context of language learning	Grammar and vocabulary learning, Sentence construction, Listening and speaking skills, Pragmatic language use, Contextual understanding, Language input processing, Learning through immersion
AI Learning Models	Neural network processing, Cognitive processing of data, Pattern recognition, Learning algorithms, Neural connections for learning tasks, Generalization across diverse data	Embodied cognition in robots, Sensorimotor feedback in AI, Sensory input for task learning, Physical interaction with environment, Robot learning through motor feedback, Motor actions influencing language processing	Language processing in AI, Natural language understanding, Text and speech synthesis, Language generation models, Multimodal language processing, Grounding language with real-world data, Language tasks involving AI and robots

In most approaches, the mind is central to language learning. It processes language through mental rules (Structuralism), embodied experiences (Cognitive Linguistics), or social contexts (Functionalism, Sociocultural Theory). Post-Structuralism places emphasis on how the mind is influenced by social power and discourse. The body serves different roles across theories. It is passive in Structuralism, active in Cognitive Linguistics, Functionalism, and Sociocultural Theory, and plays a role in constructing meaning in Post-Structuralism. Language is seen as a mental construct (Structuralism), grounded in embodiment (Cognitive Linguistics), a social tool

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(Functionalism), fluid and constructed (Post-Structuralism), and socially mediated (Sociocultural Theory).

In FLA and SLA, the mind is central to the language learning process, with the mind processing linguistic rules and cognitive strategies. In AI, the mind is represented by algorithms and neural networks that process data and recognize patterns. In FLA and SLA, the body plays an active role through gestures and social interaction. In AI, the body is integrated through embodied cognition models where robots interact with their environment, simulating human learning. FLA and SLA emphasize grammar, vocabulary, and pragmatic usage through social learning, while AI focuses on data processing, language generation, and real-world sensory feedback to simulate language learning.

As it is clear above although Generative Grammar provides a clear cognitive framework for understanding language acquisition, its neglect of the embodied aspects (such as gestures, social interaction, and physical engagement) makes it less applicable to real-world situations, where social interaction and physical presence are vital for language learning. Vygotsky's (1978) sociocultural theory, for instance, demonstrates that language acquisition is socially mediated, where physical and social interaction play critical roles (Vygotsky, 1978).

The emphasis on embodiment and sensorimotor experiences in Cognitive Linguistics aligns well with real-world situations, where language is often learned in contextual, social, and physical environments. Studies in SLA (Glenberg & Kaschak, 2002) and embodied cognition in AI (Pfeifer & Bongard, 2006) highlight that physical actions and sensory feedback are essential for understanding language. This perspective offers a more holistic view of language learning in real-life situations, making it highly applicable in both human language acquisition and embodied AI learning systems.

Functionalism closely aligns with real-world language use, emphasizing the interaction between mind, body, and language. Language acquisition in both FLA and SLA benefits from real-world contexts, as shown in Vygotsky's (1978) theory, where joint attention and social interaction help internalize language (Vygotsky, 1978). Similarly, embodied AI models (such as the ELLMER framework) (Rahimi & Ranjbar, 2021) emphasize the need for physical interaction with the environment to improve language understanding. Therefore, Functionalism appears to be highly relevant for practical language acquisition in dynamic, real-world settings.

While post-structuralism offers valuable insights into the social and political dimensions of language, it is less directly applicable in everyday language learning situations, where more concrete frameworks like Functionalism or Cognitive Linguistics (which consider both cognitive and embodied experiences) offer more practical applications. Sociocultural Theory is highly applicable to real-world language acquisition, as it directly addresses the role of social interaction, joint attention, and physical engagement in language learning. This theory aligns with findings in SLA and embodied cognition in AI systems, where social and physical interactions are crucial for effective language learning (Vygotsky, 1978). This approach is directly relevant for real-life contexts and offers significant insights into AI learning models that utilize embodied cognition.

Based on the comparison, Cognitive Linguistics and Sociocultural Theory emerge as the most applicable to real-life language learning situations, whether for human acquisition or AI models. Both theories emphasize the integration of mind, body, and language through embodiment, physical actions, and social interaction. Functionalism also offers practical insights into how language functions in social contexts, making it highly relevant for real-world language learning scenarios. On the other hand, Generative Grammar and Post-Structuralism provide valuable theoretical frameworks but are less focused on the embodied and interactive aspects of language learning, which are critical for real-life application.

4. Discussion and Conclusion

The present study explored the interconnectedness of mind, body, and language in three domains—First Language Acquisition (FLA), Second Language Acquisition (SLA), and Artificial Intelligence (AI) learning models—through the lens of cognitive linguistics, embodied cognition, and neurolinguistic evidence. The results reinforce the central argument that language acquisition is not a purely mental act but an embodied process deeply influenced by sensory-motor engagement and contextual interaction. The comparative analysis across human learning (FLA and SLA) and machine learning (AI) reveals a significant convergence in how language is shaped through embodiment, whether in human neurological networks or artificial systems trained through sensorimotor integration.

In the realm of FLA, the results affirm that children acquire language not solely by mental abstraction but through embodied interaction. The role of gesture, joint

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attention, and physical manipulation of objects contributes significantly to the internalization of linguistic structures. This finding aligns with prior Iranian studies that show how physical gestures enhance vocabulary retention and concept formation among children (Afshar et al., 2022; Khezri & Sadeghi, 2021). Similarly, international research supports this embodiment perspective by showing that comprehension of action-related words activates motor areas of the brain, indicating a tight coupling between motor systems and linguistic processing (Kiefer & Pulvermüller, 2021; Pulvermüller & Fadiga, 2019). These neurological findings bolster the argument that cognitive development, particularly in language acquisition, is grounded in the body's interaction with the physical environment.

The analysis of SLA further strengthens the case for embodied cognition. The findings demonstrate that learners who engage in motor-based activities such as role-play, gestural communication, and context-driven tasks show improved retention and comprehension of second languages. These results are consistent with earlier findings from Iranian classrooms where embodied techniques significantly enhanced student outcomes (Aslani & Noroozi, 2016; Zarei & Moini, 2020). Moreover, SLA theories grounded in embodied cognition argue that physical actions linked to language (e.g., acting out verbs or using gestures) reinforce neural connections, facilitating deeper learning (Shibata & Komori, 2022). From a cognitive neuroscience standpoint, this connection is substantiated by evidence that sensory and motor systems co-activate during language use, underscoring the embodied nature of both comprehension and production (Cochran & Osborn, 2016).

Importantly, the results also show that the emotional and affective dimensions of embodiment contribute to language learning. Non-cognitive factors, such as motivation, anxiety, and engagement, are found to shape the learner's cognitive readiness and retention capacity. These affective states are not divorced from the physical body; rather, they manifest through physiological responses that influence neural activation during learning (Guoxiong & Kuan, 2024; Kanchan, 2024). Cognitive-affective integration is especially relevant in SLA settings where learner emotions directly affect their willingness to communicate and their capacity to process complex linguistic structures (Lustiyantie et al., 2025). Thus, SLA is more effectively understood as a multimodal experience, encompassing the interaction of cognitive, bodily, and emotional systems.

In the context of AI, the findings support the hypothesis that embodied models outperform purely cognitive or algorithmic systems in language learning tasks. AI systems that incorporate sensorimotor data—such as robots equipped with cameras, tactile sensors, and movement algorithms—demonstrate superior abilities in grounding language in perceptual experience (Shahbazian et al., 2023; Zhang & Li, 2023). This embodiment enables machines to link words with objects, actions, and contexts, much like human learners. The results from this study mirror those from embodied AI research, which shows that neural networks trained through physical interaction yield more accurate and context-aware language outputs (Rahimi & Ranjbar, 2021). AI models using multimodal inputs (e.g., sight, sound, and touch) have also been shown to build more robust semantic networks, simulating human-like comprehension patterns (Mishin, 2025; Parween et al., 2025).

The findings further align with the theory of embodied construction grammar, which posits that linguistic structures arise from the repeated co-activation of conceptual and sensorimotor networks (Bergen, 2020). AI models trained under this principle demonstrate a heightened ability to process metaphorical and idiomatic language, which traditionally posed challenges for computational systems. These results indicate that language comprehension—whether biological or artificial—is enhanced when grounded in bodily and environmental context.

Additionally, the findings confirm that language functions as a cognitive scaffold for broader intellectual development. Language supports memory, abstract reasoning, and executive functions—all of which are enhanced when taught through embodied methods (Komala et al., 2025; Mohamed, 2024). In both humans and AI, engagement with language in multisensory formats strengthens the underlying cognitive processes that support learning. Neurocognitive research has shown that such multimodal experiences lead to the formation of stronger synaptic connections, better memory consolidation, and improved transfer of knowledge to new contexts (Guan, 2024; Krishnan & Vinodhini, 2024).

Furthermore, the sociocultural and anthropocentric dimensions of embodied language are evident in how meaning is co-constructed through social interaction and physical engagement. The results reflect the perspectives of scholars who emphasize that language is situated within specific cultural, physical, and interpersonal contexts (Huda, 2025; Muratkhodjayeva, 2024). These findings are particularly important in multilingual and multicultural environments where language acquisition is influenced not

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only by individual cognition but also by collective practices and embodied socialization processes (Аметова, 2024).

Taken together, the results suggest that the most effective models of language acquisition—whether in FLA, SLA, or AI—are those that incorporate embodiment as a foundational principle. These models provide a more accurate and ecologically valid representation of how language is learned, processed, and used in real-world contexts. They move beyond reductionist paradigms that isolate cognition from the body and instead promote an integrative understanding of language as a product of continuous interaction between brain, body, and environment.

Despite its comprehensive theoretical and comparative framework, the present study is not without limitations. First, the reliance on content analysis restricts the ability to assess real-time behavioral or neurological data, which would be essential for measuring embodied responses more precisely. Second, while the study integrates Iranian and international research, the findings may not fully generalize to all cultural or educational settings due to contextual variability. Third, the study does not include empirical experiments or quantitative validation of the models discussed, which would be necessary for drawing stronger causal inferences about the mechanisms of embodied language learning.

Future studies should consider integrating neuroimaging techniques such as fMRI or EEG to measure the neural activation patterns associated with embodied language learning. Longitudinal designs could also help track the development of embodied language skills across different age groups and learning environments. Additionally, cross-cultural experimental studies are needed to test the universality of embodied cognition theories in SLA and FLA, especially in underrepresented linguistic communities. Research should also explore the integration of AI-based embodied platforms in classroom settings to evaluate their pedagogical effectiveness compared to traditional instruction.

Educators should design language curricula that integrate physical movement, gesture-based tasks, and real-world simulations to reinforce linguistic structures. Language instruction should encourage social interaction and collaborative tasks that stimulate both mental and bodily engagement. Developers of AI-based language tools should prioritize embodied feedback mechanisms and multisensory input systems to improve user engagement and learning efficacy. Finally, institutions should support interdisciplinary collaboration between linguists, educators, neuroscientists, and AI engineers to create comprehensive language learning ecosystems grounded in embodied cognition.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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