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Parallels Between Motor Skill Development and Language Development in Children

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Abstract

This review study examines the parallels between motor skill development and language development in childhood from a multifaceted perspective. When developmental processes are examined, it is observed that these two areas influence each other reciprocally at neurological, environmental, and behavioural levels. Motor skills enhance a child's interaction with the environment and the frequency of exposure to linguistic input, while language development supports motor planning, attention, and executive functions, thereby enabling movement to become meaningful. Functional neuroimaging studies have revealed that motor and language functions are processed in similar regions of the brain, particularly the Broca area, inferior frontal gyrus, and mirror neuron system, which are common to both movement and language processes. The frequent co-occurrence of diagnoses such as developmental coordination disorder (DCD) and specific language impairment (SLI) supports this parallelism at the clinical level. In this context, early intervention programmes developed from a joint perspective of sports science and speech-language therapy disciplines can support children's physical and communicative potential with a holistic approach. Therefore, the widespread implementation of holistic programmes that support children's motor and language development in the preschool period can enable the early detection of developmental delays and provide support in multiple areas.

Keywords: Motor development, Language development, Child, Neurodevelopment, Mirror neuron

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INTRODUCTION

Childhood represents the fastest and most sensitive stage of human development. In this process, motor and language development are recognised as two fundamental components that directly shape not only the way an individual relates to his/her environment, but also his/her cognitive and social development (Iverson, 2010). Motor skills enable children to physically interact with their environment, manipulate objects and express themselves in a social context. Language development facilitates the symbolic expression of these interactions, the sharing of intellectual processes and the construction of social belonging (Leonard & Hill, 2014; Houwen et al., 2016). The period from prenatal to 2 years of age, defined as the first 1000 days, is the period when brain plasticity and environmental vulnerability are the most intense (Sania et al., 2019). Factors such as nutritional deficiencies, environmental stimulus deficiencies or inadequate parental interaction that children encounter during this period can negatively affect the development in motor, language and cognitive areas. In particular, low socioeconomic level, mother's education level, prenatal risks and inadequate stimulation in the early period may cause children to lag behind in language and motor skill acquisition (Araujo et al., 2020). An increasing number of studies in the literature show that there is a mutual interaction and parallelism between motor development and language development (Valentini et al., 2018). Progress in motor skills increases the child's interaction with his/her environment, which facilitates exposure to linguistic stimuli and supports expressive and receptive language skills (Iverson, 2010; Alcock, 2006). For example, gross motor gains such as sitting, crawling or walking allow the child to focus attention, orient to the object and interact more effectively with social partners. These developmental leaps prepare the ground for the acquisition of linguistic symbols (Houwen et al., 2016; Leonard & Hill, 2014). These interactions that occur during the development process determine not only the individual's quality of life but also their role in society. Research has shown that delays in early language and motor development can affect academic achievement, social adjustment, and even income levels in adulthood (Sania et al., 2019). The fact that approximately 250 million children, especially in low-income countries, do not fulfil their developmental potential may cause intergenerational transmission of social inequalities. In this context, motor development functions not only as a biological maturation process but also as a foundational platform that shapes the child's capacity for environmental exploration, social engagement, and subsequent cognitive and linguistic enrichment.

METOD

Motor Development

Motor development is the totality of age-related changes observed in movement behaviours throughout the life of an individual and the interactions of organism, environment and task that affect these changes. This developmental process becomes evident in childhood and forms a critical basis for participation in physical activity, acquisition of basic sport skills and development of general motor performance (Gallahue, 1989). From a sport science perspective, motor development is not only a biological maturation process, but also a multidimensional process shaped by environmental stimuli, exercise intensity, play environments and systematic training programmes (Clark, 2007). In addition, it is known that motor development has a wide range of effects ranging from increasing the level of physical fitness to social participation and self-confidence; it also strengthens children's motivation to participate in active life. As a matter of fact, Williams et al. (2008) found that children with high motor skill levels participated more in moderate-to-vigorous physical activities and exhibited less sedentary behaviour than their peers with lower motor competence. Moreover, the progression of motor skills—by enhancing attention regulation, environmental engagement, and imitation capacity—provides critical support for the emergence and refinement of both receptive and expressive language abilities during early childhood. Language development is one of the basic cognitive and communicative processes that enable individuals to establish meaningful, functional and social interaction with their environment during childhood. This process, which progresses from birth, is shaped by the interaction of genetic structure, neurobiological maturation, environmental stimuli and social experiences (Visser-Bochane et al., 2019). The developmental language process consists of two basic components, both receptive and expressive. If a healthy balance cannot be established between these components, the child may have serious difficulties in areas such as environmental interaction and academic success. In this context, monitoring language development in early childhood is recognised as a determining factor that directly affects the individual's capacity for learning and social adaptation in later life(Visser-Bochane et al., 2019). While receptive language development expresses the individual's capacity to grasp the meaning of sounds, words and linguistic structures in the environment, expressive language development involves the verbal expression of these concepts (Rahimpour, 2004). Developmentally, children generally develop receptive language earlier and faster than expressive language. In the first months, infants exhibit skills such as orienting towards vocal stimuli, recognising facial expressions and responding to gestures. Babbling behaviour is observed between the 6th and 9th months and the production of the first meaningful words begins around the 12th month (Rahimpour, 2004). Parent-child interaction and the intensity of verbal stimuli in these early stages of language development are

among the determining factors of linguistic competence in later periods. Motor skills are generally divided into two groups: gross motor skills and fine motor skills. Gross motor skills include movements that require coordination of large muscle groups such as running, jumping, and climbing, while fine motor skills occur in tasks where small muscle groups and hand-eye coordination are used effectively, such as writing and using scissors (McDonough, Liu & Gao, 2020). Gross motor skills form the infrastructure of movements specific to sports branches in children and facilitate the development of more complex technical skills (Goodway & Branta, 2003). Motor development in childhood progresses in predictable stages at certain age intervals. This process starts with reflexive movements from birth and continues with the acquisition of basic motor skills between the ages of 2-7. In this process, children's movement repertoire expands rapidly and a significant increase in motor competence is achieved when supported by structured sports training programmes (Benda et al., 2021). Wang et al. (2020) reported that children aged 3-6 years develop basic motor skills at an average annual rate of 20-30%; girls progress faster in locomotor skills and boys progress faster in object control.

Table 1. Normal Motor Development in Children

Age Range	Gross Motor Development	Fine Motor Development
0-3 Months	Holds head briefly at midline; raises head in abdominal position	Reflexive grasping; looking at hands
3-6 Months	Gains head control; sits with support	Holding objects with both hands; bringing objects to mouth
6-9 Months	Rotates between supine and prone positions; sits unsupported	Playing objects by changing hands
9-12 Months	Crawling starts; standing up with support; sorting movement is seen	Grasping small objects with thumb and forefinger (pincer grasp)
12-18 Months	First steps; independent walking; can bend and get up	Scribbling; pushing and pulling objects
18-24 Months	Running starts; simple jumping movements develop	Stacking blocks on top of each other; starting to eat with a spoon
2-3 Years	Climbs/descends stairs one by one; rides a tricycle; walks in a straight line	Draws circles, squares; cuts with scissors; buttons large buttons
3-4 Years	Can stand on one leg for a short time; plays simple ball games	Easily manipulates small objects; solves simple puzzles
4-5 Years	Develops skills such as jumping and hopping; imitates basic sports movements	Name writing, colouring develops protection of borders
5-6 Years	Coordination increases; jumping rope and balance movements improve	Increase in fine motor control; writing skills improve
6-8 Years	Tumbling, gaining running rhythm; progress in basic game skills	Increases speed and accuracy in handwriting; uses small hand tools
8-10 Years	Can perform more complex sports movements; develop speed, agility	Written expression skills develop; instrument use is possible
10-12 Years	Significant increase in sporting skills; strength and endurance increase	Starts to draw graphs; can use technological tools effectively
12-14 Years	Sports-specific technical skills are gained; balance, speed and strength are integrated	Fine motor skills are specialised; artistic production increases

Language Development

The stages of language development are generally universal. In the first stage (0-12 months), children react to sounds, show babbling behaviour and imitate some basic gestures. Between 12-24 months, they begin to produce meaning with one-word (holofrastic) expressions. Between 2-3 years of age, children form simple sentences by combining two or more words; the foundations of syntactic rules are laid in this period. Between the ages of 3-6, sentence structures diversify, the use of conjunctions increases, linguistic expressions of abstract concepts develop, and children begin to use complex discourse structures (Visser-Bochane et al., 2019) (Table 2.). Language development is not only an outcome of biological maturation; it is also closely related to social interaction and cognitive processes. In particular, Vygotsky's sociocultural theory emphasises that social contexts, adult-child interactions and cultural transmission play a critical role in the child's language acquisition process (Morse & Cangelosi, 2017). The interaction of parents, especially mothers, with the child in the early period is a determining factor in terms of the quantity and quality of language input. In this context, parents' frequent dialogue with the child, naming and creating common attention areas have an accelerating effect on receptive and expressive language development (Rinaldi et al., 2023). From a cognitive perspective, language learning requires the co-ordination of a number of basic mental functions such as attention, memory, symbolic thinking and executive functions. Especially between the ages of 1-3 years, children's increasing verbal expression proceeds in parallel with the development of their cognitive schemata with environmental language inputs. Neurodevelopmental theories explain this process by the interaction of the prefrontal cortex and linguistic processing areas of the brain (Morse & Cangelosi, 2017).

Table 2. Language Development in Children (Karacan, 2000).

Month/Age	Receptive Language	Expressive Language
1st month	Stops random movements with sound. Leaps with sudden sound/noise. Relaxes with a familiar sound.	Cries, makes random noises.
2nd month	Listens to the speaker, can smile.	Has a special cry when hungry. It makes sounds of pleasure, social smiling begins.
3rd month	He looks at the speaker, locates him.	When played with, it makes laughing and other pleasant sounds, utters two or more different syllables, clucks.
4th month	Understands the difference between an angry and pleased voice.	Responds to social stimuli with voice. Uses the sounds "P", "B", "M".
5th month	Identifies the sound source and reacts to it.	Sound imitation begins. It uses thick vowels like "O" and "U".
6th month	Recognises words such as "bye bye", "mama", "grandpa".	Loud protests and screaming with pleasure are observed.

7th month	Responds with gestures to expressions such as "come", "bye bye".	Makes word-like sounds.
8th month	It stops moving when its name is called.	Repeats syllables, plays "cee" game.
9th month	When "No" is said, it stops the movement.	Imitates syllables and intonations.
10th month	Gives objects with verbal request.	He says the first words, some like "uf-uf", exclamations, uses jargon language.
11th month	Responds to simple questions (where is the dog?) by looking/signalling.	"Cee" starts the game, repeats new words.
12th month	Responds to verbal requests with gestures, shows interest in speech.	Addresses familiar objects by name, uses 3+ words.
12-14 months	Weekly understands new words, recognises emotional tone.	5+ real words, sign-sound requests, frequency of meaningful words increases.
14-16 months	Object-picture identification, understanding of paired stimuli are observed.	Single word use between 7-20, consonant use increases.
16-18 months	Reaction to simple questions, fulfilment of commands with 2 instructions.	Words instead of gestures, understanding 150 words, 3-4 new words every month.
18-20 months	Reaction to verbs such as "sit", "come", "do not", showing body parts and clothes.	Imitation of 2-3 word sentences, imitation of environmental sounds, use of 10-20 words.
20-22 months	3 fulfils verbal request, distinguishes picture/object difference.	Makes sentences with 2-3 words, increases the number of words, uses a mixture of meaningful/incomprehensible words.
22-24 months	Chooses one of 5 different items, understands long sentence meaning, pronoun, suffix, complex structure.	3-word sentences, addressing oneself by name, using some pronouns, 22 words on average.
24-27 months	3+ shows small body parts, learns the names of locations within the family.	Sentences of 2-3 words, correct use of personal pronouns, asking for verbal help.
27-30 months	Understands functional questions such as "What do you eat with?", recognises objects according to their quality.	Names at least 1 colour, recognises objects, repeats 2+ numbers correctly.
30-36 months	Understands expressions such as "Give half".	He tells the events of 2-3 days ago, tells his name, asks for the word he does not understand.
36-54 months	Understands prepositions (under, behind), understands 3500-5000 words, establishes cause-effect relationship.	Pronunciation improves, speaking from the past, use of tenses, plural, singular, interjections.
Over 4-5 years old	Understands the concepts of speed, number, time, distinguishes between right and left, classifies according to their meanings.	Develops thought and storytelling, changes sentence structures, corrects mistakes.

Neurological and Functional Links between Motor and Language Development

Motor and language development are the basic developmental building blocks of childhood. These areas develop not only at the behavioural level but also at the neurological level in an intertwined manner. Functional brain imaging studies show that brain regions involved in motor control and language processing (e.g. Broca's area, cerebellum, basal ganglia and dorsolateral prefrontal cortex) often overlap. This implies that maturation in motor skills may directly affect language performance (Hanakawa, 2011; Hauk et al., 2004; Nishitani et al., 2005). The embodied cognition approach emphasises that motor systems are not only limited to movement, but also interact bidirectionally with higher-level cognitive functions, especially language and social interaction processes. According to this perspective, the ways in which children physically interact with the environment play a critical role in shaping their linguistic and cognitive worlds. For example, motoric achievements such as walking and object manipulation increase children's access to environmental language inputs, which in turn facilitates language learning (Iverson, 2010). Studies on children with neurodevelopmental disorders reveal that delays in motor and language domains are often co-occurring. Conditions such as developmental coordination disorder (DCD) and specific language impairment (SLI) show deficits not only in the respective domain but also in other developmental domains. Such comorbid difficulties suggest that these domains may be controlled by common genetic and neurological substrates (Hill, 2001; Ullman & Pierpont, 2005; Spinath et al., 2004). There is also evidence that delays in children's motor development, especially weaknesses in fine motor skills, may negatively affect both receptive and expressive language skills. In meta-analyses, significant correlations have been reported between gross and fine motor delays and language delays (Leonard & Hill, 2015). However, this relationship was generally observed more strongly in children with atypical development compared to typically developing children (Van der Fels et al., 2015).

Brain development, synaptic connections and executive functions

Brain development, synaptic connections and the development of executive functions in children provide a common ground for both sports sciences and speech and language therapy in the context of motor and language development. Brain development continues intensively especially in childhood and is shaped by neurobiological bases such as increased synaptic connections, myelination processes and cortical region differentiation (Huttenlocher, 1997; Casey et al., 2000). In this process, especially the prefrontal cortex constitutes the centre of executive functions that manage planning, attention, problem solving and linguistic processes. In childhood, synaptogenesis, the formation of synaptic connections, peaks at different times in different brain regions. For example, in the auditory cortex this process peaks in the first three months after birth, whereas in the prefrontal region it occurs at around 15 months. Connections in these regions are optimised by synaptic pruning that occurs throughout

childhood. This pruning process supports the development of executive functions by eliminating dysfunctional synapses and strengthening functional ones (Huttenlocher, 1997; Bourgeois et al., 1994). From a sports science perspective, these neurodevelopmental processes form the basis of motor control. Especially with the development of the prefrontal cortex, skills such as attention, strategic planning and motor sequencing develop in children; this provides a basis for the organisation of sports movements and the learning of complex motor skills (Giedd et al., 1999; Barnea-Goraly et al., 2005). In this context, the development of executive functions enables children to increase both coordination skills and motor learning capacities, and this development facilitates the acquisition of active living habits.

From the perspective of speech and language therapy, executive functions play a critical role in the processing and planning of expressive and receptive language and in the execution of sustainable speech. Research has shown that frontal lobe activity is present even in infancy, for example, frontal EEG activity in 6-month-old infants is associated with significant behavioural responses (Chugani et al., 1987; Bell & Fox, 1992). These neurodevelopmental foundations provide the cognitive basis for children to discriminate sounds, produce words and organise sentence structures.

Mirror neurone system and common neural substrates

The mirror neuron system (ANS) is defined as a network of neurons that is activated both when performing movements and when observing the movements of others, and plays a fundamental role in the learning of human behaviour, the development of imitation skills and social communication (Rizzolatti & Craighero, 2004). This system has been shown to involve regions such as the inferior frontal gyrus (especially pars opercularis), inferior parietal lobule and superior temporal sulcus and to regulate motor and cognitive functions simultaneously (Iacoboni et al., 1999; Aziz-Zadeh et al., 2006). It is observed that motor and language development processes in children are largely based on similar neuronal structures. In particular, the pars opercularis is a critical centre for both motor control of articulation and mental representations of movement patterns learned through observation (Rizzolatti & Arbib, 1998). This region has been shown to be activated in both linguistic and motor tasks, providing a neurobiological basis for the parallelism between motor development and language acquisition (Fadiga et al., 2002). Functional MRI studies have shown that during imitation tasks such as finger sequencing in children, these language-related regions are activated simultaneously with motor and premotor regions (Reynolds et al., 2015). Imitation skill, which is one of the most basic functions of the ANS, is critical for both the acquisition of motor skills and the learning of verbal communication patterns in childhood. Imitation serves as a bridge that enables the learning of not only physical movements but also phonetic structures and gesture-mimics (Gallese et al., 1996; Heiser et al., 2003).

DISCUSSION AND CONCLUSION

Parallelism between Normal Motor Development and Language Development in Children

Motor and language development are two basic developmental areas of childhood that affect each other. Childhood is a critical stage in which both motor skills and linguistic abilities develop rapidly. Although these two areas of development are often considered as independent of each other, recent neurodevelopmental and behavioural studies in early childhood show that there is a significant and reciprocal interaction between motor skill development and language development (Iverson, 2010; Leonard & Hill, 2014; Libertus & Violi, 2016; Gonzalez et al., 2019). In this context, this parallelism, which creates a common working ground for both sports sciences and speech and language therapy, plays a critical role in designing holistic intervention programmes that support children's development. The process of motor development facilitates children's physical interaction with the environment, allowing them to be exposed to linguistic stimuli more frequently and in various ways. In particular, motor skills such as crawling, walking and object manipulation indirectly affect expressive and receptive language development by supporting the child's ability to direct attention, object recognition and symbolic representations (Iverson, 2010). In the sport sciences literature, this situation is explained through the effect of participation in physical activity-based programmes at an early age on cognitive and communicative skills. When analysed at the neurological level, it is seen that motor and language processes operate in similar regions of the brain. In particular, regions such as Broca's area, inferior frontal gyrus and cerebellum have been shown to be associated with both movement coordination and speech production (Wood, 2004). This overlap reveals that motor systems are linked not only with movement control but also with symbol production and verbal expression processes. The mirror neuron system provides the cognitive counterpart of the common neural infrastructure between these two areas; it supports that children learn by imitating both physical movements and verbal expressions (Rizzolatti & Craighero, 2004). Studies on children with developmental disorders also confirm this parallelism. Diagnoses such as Specific Language Impairment (SLI) and Developmental Coordination Disorder (DCD) are often seen together, indicating that these two fields are intertwined at the genetic and neurodevelopmental level (Hill, 2001; Ullman & Pierpont, 2005). This situation reveals the necessity of implementing both sports sciences and language therapy interventions in a holistic and coordinated manner, rather than separately. In particular, the acquisition of gross motor skills (e.g. sitting, walking) supports receptive and expressive language development by enabling children to interact more actively with their environment and be exposed to richer linguistic input (Andalò et al., 2022). Functional neuroimaging studies have shown that motor

and linguistic processes are processed in common regions of the brain (e.g. Broca's area) and that motor development overlaps with language processing systems at the neuroanatomical level (Rizzolatti & Arbib, 1998; Wang et al., 2014). Moreover, the active role of the mirror neurone system in both action and language interpretation provides a neural infrastructure supporting this parallelism (Fischer & Zwaan, 2008). In a cross-sectional study conducted by Mulé et al. (2022), significant relationships were observed between motor performance and language development in children aged 3-5 years. In particular, success in motor tests such as balance (standing on one leg), flexibility (Sit and Reach) and jumping skills were positively correlated with phonological memory and sentence comprehension scores from language subtests. These findings suggest that motor skills play a critical role not only in physical fitness but also in the development of cognitive and linguistic functions. Similarly, a longitudinal study by Andalò et al. (2022) found that gross motor coordination skills have an impact on specific language categories such as spatial vocabulary and verb production between 18-30 months. Furthermore, Libertus and Violi (2016) found that early acquisition of sitting skills was associated with a larger receptive vocabulary at 10 months.

According to the systematic review by Gonzalez et al. (2019), gross and fine motor skills influence language outcomes in different developmental ways; both skill types make significant contributions in predicting expressive and receptive language performance. However, although motor development alone is not sufficient for language development, it is a supportive developmental building block. In this context, this parallel and reciprocal interaction between motor and language development in children should form the basis of holistic intervention approaches for both sport sciences and speech-language pathology. Movement-based programmes that support early motor development can optimise not only children's physical competence but also their linguistic and cognitive development. Motor and language development are parallel processes that support each other in terms of neurological, behavioural and environmental factors in childhood. Sports science specialists can enrich linguistic interaction environments while developing children's motor skills; speech and language therapists can achieve more effective results by integrating methods based on motor actions while supporting language development. Interdisciplinary interaction and cooperation paves the way for the creation of holistic models that serve the multidimensional development of children by protecting the boundaries of each field's own expertise. This study revealed that motor and language development in childhood are processes that progress in parallel and indirectly support each other with the influence of neurological, behavioural and environmental factors. Physical activities and movement-based play environments enrich children's linguistic experiences by improving their social interaction skills, which increases the effectiveness of structured interventions applied by speech and language therapists. On the other hand,

therapeutic interventions aimed at supporting language development may also indirectly contribute to the use of motor skills by strengthening the child's communication with his/her environment.

RECOMMENDATIONS

It is recommended that intervention programmes for these areas be structured with an interdisciplinary approach, given that motor and language development are mutually supportive processes in childhood. The development of movement-based programmes, collaboratively designed by sport science specialists and speech and language therapists, holds significant potential for enhancing the physical and communicative abilities of children. Furthermore, a holistic assessment of children who are at risk of developmental delays, coupled with concurrent monitoring in both motor and linguistic domains, will facilitate the development of more efficacious intervention strategies.

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