Perspective

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Multifactorial influences on cognitive development: A neurobiological, environmental, and educational perspective

H Gambheera

Abstract

Cognitive development arises from a dynamic interplay of genetic, neurobiological, environmental, and experiential factors. This paper explores the foundational mechanisms underpinning cognition, including the role of the hippocampus in memory formation and the influence of synaptic plasticity on long-term learning. It examines how environmental enrichment, parenting quality, nutrition, and physical activity shape cognitive outcomes through epigenetic mechanisms. The detrimental impact of chronic stress, socioeconomic disadvantages, and exam-related academic pressures on cognitive capacity is analyzed. Furthermore, the paper emphasizes the role of novelty exposure in enhancing learning and memory and explores the neurobiological basis and societal significance of empathy. The findings underscore the need for integrated strategies that foster cognitive health in early life, highlighting the importance of experience-based learning, emotional support systems, and enriched environments in optimizing developmental trajectories.

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Introduction

Cognitive development is central to an individual's ability to think, learn, remember, and engage with the world. It is not a linear or isolated process but one shaped by an intricate interaction between neural circuitry, sensory input, environmental stimulation, and socio-emotional factors. Understanding the multifactorial influences on cognition is vital for improving educational practices, mental health outcomes, and developmental interventions. This paper explores the biological substrates of cognition, the modulating role of environmental and psychosocial inputs, and the long-term implications for learning and behavior.

Theoretical background: cognition and consciousness

Cognition encompasses a broad set of mental processes related to acquiring and processing knowledge. These include attention, perception, memory, reasoning, problem-solving, and language comprehension. Cognition operates at both conscious and unconscious levels and may involve both concrete and abstract thought.

Philosophical inquiry into cognition dates back centuries. René Descartes' "Cogito, ergo sum" ("I think, therefore I am") emphasized cognition as essential to human existence (Encyclopedia Britannica, 2024). Conversely, Aristotle proposed the "tabula rasa" theory, suggesting that individuals are born without innate ideas, and all knowledge is acquired postnatally through the five senses (Aristotle, as cited in Britannica).

Neurobiological Foundations of Cognitive Development

Role of the hippocampus in memory encoding

The hippocampus is central to the encoding and consolidation of long-term memory. It receives sensory information through the entorhinal cortex and forwards it for encoding and storage. This process involves forward information processing, pattern separation (distinguishing between similar memories), and pattern completion (recalling full memories from partial cues) (Rolls and Treves, 2011).

Synaptic plasticity and long-term potentiation

Memory formation is supported by synaptic plasticity, particularly long-term potentiation (LTP), a mechanism in which high-frequency neural stimulation strengthens synaptic connections. This neural remodeling enables long-term storage of learned experiences (Bliss and Collingridge, 1993). Structural changes from LTP, such as increased dendritic branching and synaptogenesis, are integral to neuroplasticity and cognitive flexibility.

Interaction with prefrontal cortex

During memory retrieval and decision-making, the hippocampus interacts with the prefrontal cortex-responsible for executive functions such as planning, problem-solving, and emotional regulation. This cooperation demonstrates how cognition is influenced not only by experience but also by current contextual demands.

Epigenetics: Gene-environment interactions in cognition

Genes do not express independently; rather, environmental factors modulate genetic expression in a process known as epigenetics. Waddington (1942) defined epigenetics as the causal interaction between genes and their products in shaping phenotypes. Positive environmental inputs-such as nurturing parenting and enriched learning environments-can enhance gene expression relevant to cognitive development (Purva et al., 2022).

Enriched environments lead to increased cortical thickness, dendritic complexity, and neurogenesis, even without altering the genetic code (Diamond, 2001). These adaptations demonstrate how early-life experiences contribute to long-term cognitive architecture.

Environmental and parenting influences

Positive parenting and cognitive growth

Parents serve as the primary socializing agents in early development. Positive parenting-characterized by emotional warmth, responsive caregiving, and consistent support – has been shown to enhance a child's emotional security, cognitive maturity, and resilience (Purva et al., 2022). Effortful control by parents also supports the child's regulation of attention, emotion, and behavior.

The Role of enriched environments

Cognitive enrichment arises from exposure to complex, organized, and stimulating settings. Factors such as quality housing, diverse educational materials, social interaction, and opportunities for motor and sensory engagement all contribute to neural development (Bradley and Corwyn, 2001). These conditions correlate with increased grey matter volume, enhanced memory, and improved problem-solving skills.

Nutrition, physical activity, and cognitive outcomes

Proper nutrition is fundamental for cognitive health. Nutrients affect neurotransmitter synthesis, synaptic plasticity, and brain metabolism from infancy through adulthood (Nieto, 2024). Physical exercise also plays a neuroprotective and neuromodulatory role, improving attention, executive function, and mood (Mandolesi et al., 2018; Zeng et al., 2017).

Exercise induces neurogenesis, gliogenesis, and angiogenesis, contributing to better cognitive performance and mental health. These findings emphasize the holistic integration of lifestyle factors in supporting brain development.

Learning, memory, and higher-order thinking

Learning, particularly when experience-based, rewires the brain by creating new synaptic connections and neural pathways. Cognitivism – the theory focusing on mental processes – posits that learning enhances memory, reasoning, and information processing (Kurt, 2023).

Higher-order thinking involves synthesis, hypothesis generation, and reflective problem-solving. Critical thinking is defined as the "intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, or evaluating information" (National Council for Excellence in Critical Thinking, 1987). Unfortunately, many educational systems continue to emphasize lower-order skills such as rote memorization.

Stress, socioeconomic status, and cognitive impairment

Chronic stress, particularly during childhood, has a detrimental effect on the developing brain. Prolonged exposure to adversity – whether due to academic pressure, poverty, or trauma – reduces hippocampal volume and impairs neuroplasticity (McManus et al., 2022). This leads to deficits in memory, attention, and executive function. Children growing up in low socioeconomic environments are disproportionately affected due to limited access to cognitive enrichment and increased exposure to psychosocial stressors. Educational systems that promote high-stakes examinations without emotional support risk compounding these challenges.

Novelty and cognitive stimulation

Novelty activates neuromodulator systems in the brain, enhancing learning, motivation, and perception

(Schomaker and Meeter, 2015). It also improves long-term potentiation, reinforcing the neural mechanisms underlying learning (Bliss and Collingridge, 1993). Spatial novelty-new or unfamiliar environments – triggers exploratory behavior and strengthens cognitive flexibility.

Empathy and social cognition

Empathy is critical for social functioning and is divided into two types:

- Affective empathy: The emotional resonance with another's feelings.
- Cognitive empathy: The ability to understand another's mental state (also called mentalizing).

The mirror neuron system, involving the inferior frontal cortex and premotor areas, supports empathetic processing (Schomaker and Meeter, 2015). Empathy can be cultivated through social learning, training, and experiential exposure and is essential for social cohesion, moral development, and community resilience.

Conclusion

Cognitive development is a complex, multifactorial process shaped by neurobiology, environment, parenting, and personal experience. While genetics provides a foundational blueprint, the expression of cognitive capacity is significantly influenced by early-life experiences, stressors, and enrichment. Interventions aimed at improving parenting practices, reducing academic stress, enhancing physical health, and fostering empathy can play a pivotal role in optimizing cognitive outcomes.

Future research should explore scalable educational and policy interventions that integrate these findings into real-world settings, particularly in resource-limited contexts. A paradigm shift toward experience-based learning and emotionally supportive environments may yield the most profound and sustainable benefits for cognitive development.

H Gambheera, National Institute for Mental Health, Angoda, Sri Lanka

Corresponding author: H Gambheera

E-mail: hgambheera@gmail.com

References

Aristotle. (n.d.). Tabula rasa. Encyclopedia Britannica.

Bliss TV, Collingridge GL. A synaptic model of memory: Long-term potentiation in the hippocampus. Nature 1993; 361(6407): 31-39. https://doi.org/10.1038/361031a0

Bradley RH, Corwyn RF. Home environment and behavioral development. Merrill-Palmer Quarterly, 2001; 47(2): 165-87. https://doi.org/10.1353/mpq.2001.0007

Diamond, M. C. (2001). Response of the brain to enrichment. Academic Press.

Kurt, S. (2023). Cognitivism: Learning theory, strategies, and examples.

Mandolesi L, et al. Effects of physical exercise on cognitive functioning and wellbeing. Frontiers in Psychology 2018; 9: 509. https://doi.org/10.3389/fpsyg.2018.00509

McManus E, et al. The effects of stress across the lifespan on the brain. Neurobiology of Stress 2022; 19: 100447. https://doi.org/10.1016/j.ynstr.2022.100447

Nieto MRP. (2024). The impact of nutrition on cognitive development. Technológico de Monterrey. https://doi.org/10.31579/2637-8914/244

Purva DL, et al. The effect of parenting and the parent-child relationship on a child's cognitive development: A literature review. Cureus 2022; 14(8): e30574. https://doi.org/10.7759/cureus.30574

Rolls ET, Treves A. The neuronal encoding of information in the brain. Progress in Neurobiology 2011; 95(3): 448-90. https://doi.org/10.1016/j.pneurobio.2011.08.002

Schomaker J, Meeter M Short- and long-lasting consequences of novelty on cognition. Neuroscience and Biobehavioral Reviews 2015; 55: 268-79. https://doi.org/10.1016/j.neubiorev.2015.05.002

Waddington CH. The epigenotype. Endeavour 1942; 1: 18-20.