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CoLab EVIDENCE REPORT

Brain development in early childhood

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ABOUT COLAB:

CoLab brings together families, clinicians, educators, policy makers, other practitioners and researchers to provide evidence to improve service delivery and community capacity to meet the needs of children, families and communities who are experiencing vulnerability. Our vision is that young children in Australia develop, learn and thrive so they can build a better future for themselves and their communities. CoLab has three priorities, including: providing better support to families experiencing adversity; advocating for place-based approaches to improve the ways that families, services and communities work together, and; advancing the economic understanding of early childhood, with a focus on where the best early investments can be made. CoLab was launched in 2017 through a partnership between Telethon Kids and the Minderoo Foundation, made possible by Minderoo's founding commitment to ensure every Australian child gets the best possible start in life.

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Brain development in early childhood

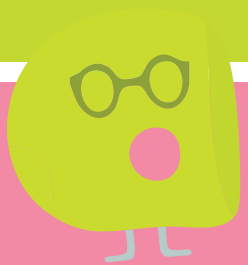
HIGHLIGHTS

- During the first few years of life, **more than 1 million neural connections** are formed within the brain every second; these neurons and their connections are the **"bricks, mortar and wiring"** of brain-building.

- How a child experiences the world in the early years can literally shape **the structure and function** of their brain.

- Safe and nurturing relationships strengthen the neural pathways and connections in a young child's brain to provide a **stable foundation for lifelong health and wellbeing.**

- If a child is exposed to **"toxic stress"** such as extreme poverty, neglect or abuse, **the architecture of the developing brain is weakened.**



- However, the experience of **at least one stable and responsive relationship** with a parent or caregiver can help protect against the damaging effects of toxic stress on children's brain development.

Brain development in early childhood

Introduction

The early years of life are characterised by significant opportunity, rapid change and accelerated development which is unparalleled by any other subsequent stage of life [1–3]. This Evidence Report highlights the importance of the early years and the neuroscience of early brain development and describes the crucial role of relationships, experiences and stress in shaping the developing brain structure and function.

The beginning of lifelong health

From conception through to the start of school, early childhood development is a complex and interactive process, occurring at a rapid pace, leading to the emergence of increasingly complex behaviours and skills [4, 5]. What happens within these years and the experiences to which a child is exposed to is paramount because it lays the foundations for lifelong health and wellbeing [3, 6].

When a child has a healthy and positive start in life this can strengthen their biological systems and enable them to successfully navigate everyday challenges, develop a sense of personal wellbeing, build relationships and reach their full potential [7, 8]. Conversely, a poor start can undermine development, weaken physiological responses, alter brain development and restrict a child's capacity to develop a diversity of competencies and thus, limit their active contribution to their community [7]. Therefore, investment into the early years can have far-reaching consequences not only for the child but also for future generations [8, 9] and on the future prosperity and productivity of society [3].

The science of brain development

Development of the brain begins within the first few days after conception and continues into the adult years [10]. This development is complex, dynamic and, contrary to previous beliefs, involves a delicate balance between 'nature and nurture' (biology and the environment) [11, 12]. To understand how brain development takes place in these early years, it is essential to firstly understand the basic structure and functions of the brain.

Soon after conception, the formation of the neural tube begins [13]. This neural tube is the precursor to the central nervous system and its associated cells, including neurons. As the brain develops, neurons begin to migrate to designated locations to create the numerous structures of the brain [14]. Neurons and their connections are the "bricks, mortar and wiring" of brain-building, providing a sturdy or weak foundation for life long health, wellbeing, learning and behaviour [15]. During the first few years of life, more than 1 million neural connections are formed within the brain every second [16]. After this period of rapid proliferation, these connections are reduced through a natural process referred to as pruning [17, 18]. Early childhood experiences influence which connections are pruned and which are strengthened [15, 19, 20].

Many parts of the brain develop in a predictable sequence, from the bottom up. The brain stem (connected to the spinal cord) develops first and is critical to sustaining survival as it regulates functions such as breathing, heart rate and blood pressure. Unlike the brain stem, the cerebellum and the limbic system (including the thalamus, hypothalamus, amygdala and hippocampus) is underdeveloped at birth. The cerebellum is primarily responsible for posture, balance and coordination [21], whereas the limbic system is responsible for relaying sensory information and for managing activity, hunger, thirst, body temperature and memory [22]. The cerebral cortex, which sits above the limbic system, is the largest part of the brain, and divided primarily into four main lobes *(see Figure 1)*.

- **Occipital lobe:** responsible for vision
- **Temporal lobe:** responsible for hearing, language and social understanding
- **Parietal lobe:** responsible for body sensations such as heat, cold, pressure and pain
- **Frontal lobe:** responsible for memory, abstract thinking, planning, self-regulation, attention, motivation and goal-directed behaviour [22].

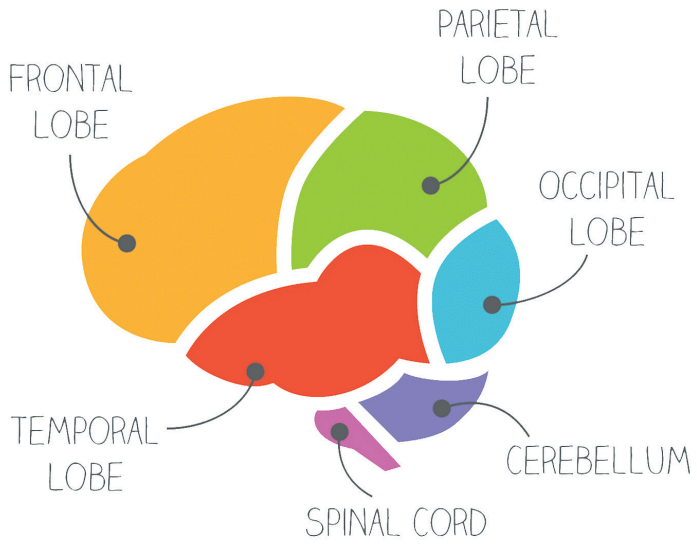


Figure 1: Anatomy of the brain

Source: *Professional Development Dimensions, 2017* [23]

As the brain develops, neural circuits become increasingly complex, and therefore higher level skills are difficult to master if lower level skill development has been compromised [12]. Given the complexity of some of the cerebral cortex functions, parts of the cortex continue to develop into the adult years. Table 1 highlights key aspects of brain development in the early years.

Table 1: Brain development in the early years

Age	Brain Development
Newborn	Brain stem is the most developed area Significant development of vision areas of the brain Able to recognise human faces Recognise family members' and significant caregivers' voices Early sensory motor skills
Babies	Development of head control and early motor skills Visual areas of the brain continue to develop Growth in the areas associated with learning and memory Language circuits strengthen
Toddlers	Rapid motor skill development Language areas of the brain experience increased development of synapses and interconnection Increased ability to complete more complex tasks Development of recognition of the self and self-awareness Understanding of consequences of actions improve Greater capacity for complex thought and cognitive flexibility
Preschoolers	Further development of language areas of the brain Greater integration of sensory and motor areas Greater capacity to manage emotions Development of frontal lobe associated with greater skills in reasoning and understanding complex ideas.

Source: KidsMatter Early Childhood, 2014

Sensitive periods of brain development

Certain parts of the brain are exceptionally sensitive to the environment or experiences during certain times, known as critical or sensitive periods [24]. These sensitive periods offer unique windows of opportunity for development and begin and end at different ages, for different parts of the brain. Sensitive periods related to vision, hearing and touch, for example, end in the first years of life, whereas sensitive periods for communication, reasoning and decision making all take place

at later stages of child development when higher levels of the brain are developing [3, 12]. Similarly, the development of emotion takes place throughout early childhood due to its reliance on the "emergence, maturation, connection and change in the complex neural networks in multiple areas of the brain"[12] and hence, shapes a child's overall wellbeing and capacity for optimal learning [12, 22].

Whilst these sensitive periods exist, research also suggests due to the plasticity of the brain in the early years, children may be able to recover, or make up for missed experiences [21]. However, brain plasticity does decrease substantially over time. Therefore, providing the right conditions for healthy development early produces better outcomes than trying to address problems later.

The role of relationships and experiences in brain development

Child development research indicates the experiences a child has within their early life may not only influence the developing architecture of their brain, but may also influence the expression of genes and how they are activated, if at all. In other words, exposure to both positive and negative experiences can "leave a chemical signature on the genes. These signatures can range from temporary to permanent, but all affect how easily the genes are switched on or off" [3]. This field of research, known as epigenetics, highlights how relationships and environments can all shape early brain development, learning and lifelong health and behaviour [25, 26]. Nurturing stable and predictable experiences, for example, which foster rich learning opportunities support healthy brain development and positive genetic potential [3, 27]. Conversely, if a child is exposed to highly stressful early life experiences which are filled with threat, uncertainty, neglect or abuse, this can disrupt brain development and impact response systems for managing adversity later in life [3].

The family environment and relationships with caregivers are integral in shaping a child's skill development in the first few years of life [28, 29]. Such relationships shape all aspects of a child's development, including their social, emotional, intellectual and behavioural development, along with later life outcomes including self-confidence, motivation to learn and school achievement. Biologically, relationships can also influence a child's regulation of stress responses, immune system competence and early health-related behaviours [7]. This development is driven by reciprocal 'serve-and- return' interactions, whereby a child seeks to interact with the adults who care for them. These 'serves' for interaction may be through babbling, gestures and facial expression and responsive adults who 'return' these serves respond through similar vocalisation and by providing emotional support [3, 10]. When a lack of response to these invitations for interaction is received, it can weaken the developing brain and consequently, lead to future learning, behaviour and health impairments [15].

The impact of stress on brain development

When children do not have the opportunity to experience predictable and responsive relationships with caregivers, or have access to protective, safe environments [30], this can increase stress hormones, cause permanent changes in brain structure and function and cause physiological disruptions which become biologically embedded, resulting in an increased risk of disease and illness including cardiovascular disease, type 2 diabetes and depression [11, 30–32].

Some stress is normal and an important aspect of child development as it helps a child to learn how to cope with adversity. However, when this stress is extreme or ongoing and the protection of a responsive caregiver is unavailable, this can have negative consequences on development and lifelong health [3]. To clearly understand the degree to which stress can impact development, three levels of stress responses have been identified.

These include:

- **Positive stress response:** A normal, moderate and transient level of stress which is an essential part of healthy development. Positive stress tends to be characterised by a short-term increase in blood pressure and heart rate along with mild increases in stress hormone levels.
- **Tolerable stress response:** This level of stress activates the body's alert systems to a greater degree than positive stress and is related to a more severe or longer-lasting threat. If this stress response is time-limited and buffered by the protection of a supportive caregiver, then this enables the brain to recover from the potentially damaging effects of this stress.
- **Toxic stress response:** Toxic stress responses occur as the result of the body's alert systems being activated strongly, and for a prolonged period of time without the protection of a supportive caregiver relationship. Toxic stress responses can be triggered through poverty, physical or emotional abuse, chronic neglect and repeated exposure to violence. This level of stress response can disrupt brain architecture along with other organs and thus, increase the risk of both physical and mental health illness.

The limitations of neuroscience

The neuroscience of early development has made a necessary and invaluable contribution to understanding the core foundations underpinning learning, behaviour and lifelong health [3]. However, neuroscience alone is insufficient to explain what happens in the early years, and it is essential that the impact of social, psychological and behavioural factors is not overlooked [12]. To achieve breakthrough impacts in early childhood, it is necessary to integrate multiple sources of knowledge that can enhance our understanding of how to improve early childhood development [3, 33]. By enhancing our capacity to use all available evidence effectively, we can better realise "the importance of good early childhood development as a fundamental right of every child" [33, 34].

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