Focus on zero to three (Part 2)
The Brain: Structure and Function

ARTICLE

In **Focus on zero to three (Part 1)**[1] we explored the implications, new knowledge and information gained throughout the last decade of brain research. We looked at how the brain develops, forms connections and 'knows' which connections to keep. In this fact sheet, **Focus on zero to three (Part 2)** we will look at the brain's structure and function to create a framework for learning about children's growth and development. Understanding the fundamentals of brain function and development provides us with an insight into the relationship between different areas of development, including social, emotional, physical, language, behavioural, and cognitive. We are then more able to identify caregiving practices that support optimal development.

At birth, the human brain is undeveloped and few of the brain's areas are organised and fully functional. It is during childhood that the brain matures and our brain related capabilities develop in a sequential fashion. Just as we crawl before we walk, and we babble before we talk, so does our brain develop from simple to complex. The development of the brain during infancy follows this bottom up (or sequential) structure. The most regulatory, lower regions of the brain develop first; followed, in sequence, by adjacent but higher and more complex regions [2]

The human brain is an amazing organ. It is responsible for all of our thoughts, feelings and behaviours. It enables us to create, to imagine and to hope. It allows us to communicate, to learn, to interact with others and to resolve conflict. In order to do all these things, our brain must organise its 100 billion individual nerve cells (neurons) into efficient systems that sense, process, perceive, store and act on the continuous sensory input from the environment: the physical sensations, the sights, sounds, tastes, smells and touches.

Our brains don't automatically 'pop' into existence capable of doing all these things. The brain begins to develop in utero from just a few cells and, by about age three, the child's brain grows to be 80 per cent of the size of an adult's brain. (This is really disproportionate to the growth of the body. Imagine if a three year old was 80 per cent adult sized. Child Care Services would need to be much bigger!) The brain grows into a dynamic and ever changing biological system which is the product of our genetic potential and our history of experience.

Experiences – repetitive, consistent, predictable and nurturing experiences – are required to express each child's underlying genetic potential. The experiences of early childhood play a key role in determining the brain's organisation and capabilities. The experiences, environments and opportunities we provide our children help determine their strengths and create their vulnerabilities. If a child's world is chaotic, violent and emotionally or cognitively impoverished, their potential will remain unexpressed or less than optimal. If the child's world is safe, nurturing and rich in social, emotional and cognitive opportunities, he or she will flourish.

The brain's key actions

Our brain helps keep us alive and thriving while we develop. Once mature, our brain allows us to procreate, protect and nurture the next generation. Our brain is designed to help us survive as a species, to reproduce and become caregivers. Our sensory organs (eyes, ears, nose, taste, and touch) tell us what is going on in the outside world. The brain senses and processes incoming sensory signals, stores elements of this information, and acts on the input. All sensory signals (inputs) begin a molecular process in the brain that alters the brain's structure (the connections that it makes and keeps[3]) and function. The way that this occurs depends on the '…pattern, intensity and frequency of neuronal activity produced by *sensing, processing and storing* signals.[4]'

The more a particular pattern of neuronal activity occurs; i.e. the more often the same sensory experiences are repeated, the more indelible the 'memory' created.

[1] RUCSN Newsletter Issue 2 (2000)

[2] We discuss this in more detail on pages 2-3

[3] Focus on Zero to Three (Part 1) RUCSN Newsletter Issue (2000) p 4-5.

'Throughout life, the brain is sensing, processing and storing patterns of neuronal activation (i.e. making memories) that correspond to various sights, sounds, smells, tastes and movements. Using various modes of memory (e.g. cognitive, emotional, motor) the brain stores these patterns, making associations between the multiple sensory stimuli that co-occur, creating templates of experience against which all future experience is matched. ……..Take the visual image of a mother's face. If no other face has ever been seen by the infant, (he/she) will create some neural templates of the basic features of a face – eyes, nose, mouth, expressions. When the infant sees father, the neural templates for face are in place and only minor modifications need to be stored.' [5]

The brain requires patterned activity to effectively develop and organise its systems. Imagine trying to learn a language if you only heard random words without the context, grammar and syntax of the language (i.e. the pattern of use). Even if you heard and perceived all the words, you could not develop language. Random exposure to words without an overall organising pattern would lead to atypical development of speech and language. This holds true for all learning experiences, including cognitive, emotional and social development. Repetitive, patterned and consistent experiences allow the brain to develop a well organised neural system.

THE HIERARCHICAL STRUCTURE OF THE BRAIN

The brain, at birth, is undeveloped. During its development it organises and grows in a logical and sequential fashion, starting from the lowest most regulatory regions of the brain and proceeding up through the more complex parts of the brain responsible for more complex functions. Healthy development in one region is dependent on the healthy development of lower brain regions that take place earlier in the developmental process.

To make it easy to understand, the human brain can be divided into four areas: brainstem, diencephalon, limbic system and neo cortex. Some of the key functions of different parts of the brain are outlined in Diagram 1. The brain areas store information related to the functions for which they are responsible. For example, the cortex stores cognitive information such as names, faces and facts; the limbic system stores emotional information such as fear, pleasure and sadness; the diencephalon stores 'motor-vestibular' information such as handwriting, riding a bike and swimming; the brainstem stores 'body state' information such as our physiological response to stress, trauma, anxiety and arousal, together with controlling heartbeat, body temperature, respiration and autonomic nervous system functions.

The complexity of structure, cellular organisation and function increases from the lower, most simple area, the brainstem to the most complex, the neocortex. The most complex part of the brain is the cortex and 60 per cent of all of the neurons in the brain are in the outer *1cm of the surface of the cortex.* Matching this increasing complexity of structure, is increasing complexity of function together with increasing plasticity (ability to change). The simplest regulatory functions of the lower brainstem areas are the most genetically determined and have the least variation and individual difference of response – there is a very limited behavioural repertoire at this level. As we go up the brain hierarchy, the impact of experience becomes increasingly important, individual differences abound and there is a wide range of behavioural responses available.

'USE DEPENDENT' DEVELOPMENT

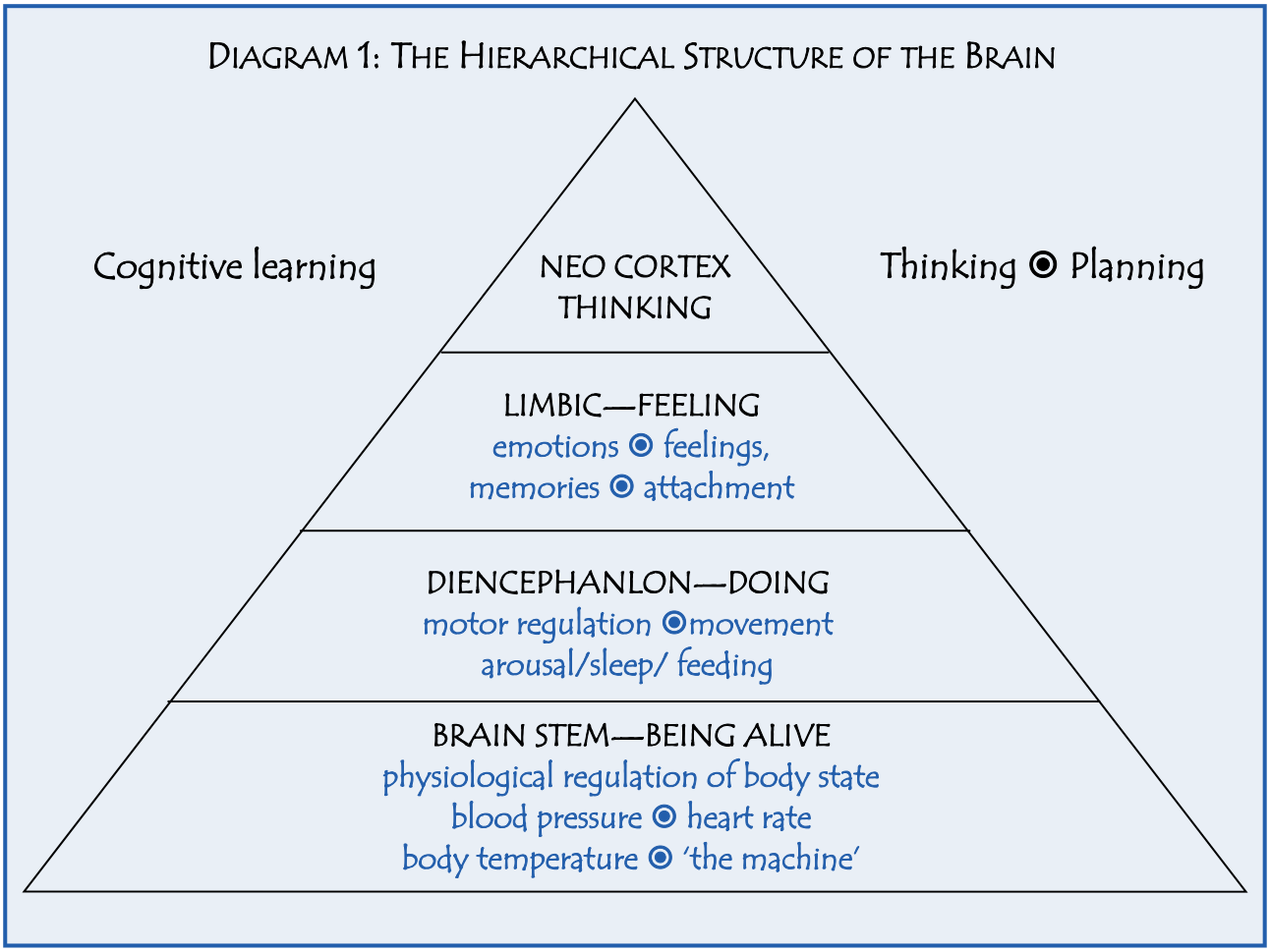
The normal organisation of any brain area or capability is 'use dependent'; i.e. it depends on the presence, pattern, frequency and timing of experiences during development. The more patterned the activity (e.g. music, reading, conversation) the more the brain regions responsible for these tasks will organise and be functionally 'healthy'. Patterned repetitive activity results in patterned neuronal activity that changes the brain. These experiences help build in our capacity to better perform those functions and to improve with practice. For example, hearing language helps to develop speech and language capabilities, practising piano helps to develop fine motor and rhythm reading capabilities and increases children's capacity for verbal comprehension and abstract reasoning. Children exposed to consistent, predictable, nurturing experiences that are developmentally appropriate will develop neurobiological capabilities that will increase their chances of future health, happiness, productivity and creativity. The child with a neglectful, chaotic or disorganised environment will have significant problems in many areas of functioning.

Play is essential for children to provide those repetitive experiences that improve and express the

[4] Perry, B D (2000) *Brain Structure and Function I: Basics of Organisation*. Child Trauma Academy Interdisciplinary Education Series, Vol 2, No 3, p 4.

[5] Perry, B D (2000) op. cit., p 5-6.

DIAGRAM 1: THE HIERARCHICAL STRUCTURE OF THE BRAIN



THE IMPORTANCE OF PLAY FOR HEALTHY BRAIN DEVELOPMENT

Central to a child's healthy development is the opportunity to act on their natural curiosity – to explore, to play and, thereby to learn. Children's play mirrors the process of sequential development. Babies play with their feet and hands, toddlers practise motor skills, and fantasy play encourages socio-emotional and cognitive development.

As children grow, their complexity of play also grows. Solitary, parallel, dyadic and then group play develops in sequence with the developing social capabilities of the child. At each stage of development, it is play and the repetitive elements of play that help organise neural systems which are responsible for more complex motor, social, emotional and cognitive skills. For example, in early childhood, when the brain is developing motor-vestibular capabilities, there is much more gross motor play than in adolescence. Play opportunities must be provided in an appropriate sequence that matches the child's level of neurodevelopment. This matching process depends on understanding the child's development in key areas: physical/motor, behavioural, emotional, social and cognitive.[6]

[6] Perry, B Hogan, L and Marlin, S (2000) *Curiosity, Pleasure and Play: A Neurodevelopmental Perspective.* p3

child's potential in all areas of brain growth and development. We must never underestimate the need for consistent, predictable, patterned and frequent opportunities for play in a child's life.

WINDOWS OF OPPORTUNITY

Most of the brain's sequential and use dependent development and organisation takes place in early childhood. Remember that the brain grows to about 80 per cent the size of that of an adult by age three. This same three years olds brain is also twice as active as that of an adult.[7] It is in this time period that the foundations are being laid for life long learning. It also means that – of all the experiences through our life span – those of early childhood have the most powerful and enduring effects on brain organisation and function.

Critical Periods

Are times in development during which a set of signals **must** be present for neural systems to differentiate normally.

Sensitive Periods

Are times in development when an undifferentiated neural system is especially receptive or sensitive to a set of signals

KEY POINTS

Brain Organisation and Function

- The brain is not a single system. It has many interacting and interconnected systems organised in a specific hierarchy – with the most complex (cortex) on the top and the least complex (brainstem) on the bottom.
- Different parts of the brain (systems) are responsible for different functions; e.g. the cortex is responsible for thinking, the brainstem is responsible for states of arousal.
- The brain's systems are networks of nerve cells (neurons). These neurons are continuously changing (in chemical and structural ways) in response to 'signals' from other parts of the brain, the body or the environment; e.g. sight, sound, taste, smell.
- Changes in neurons allow the storage of information (memory).
- Different parts of the brain store memories specific to that part of the brain enabling different types of memory – e.g. cognitive (names, phone numbers), motor (typing, riding a bicycle), affect (sadness).
- The brain stores information in a use-dependent fashion. The more a neurobiological system is 'used', the more that state (and the functions associated with that state) will be built in – for example, practising the piano, memorising a poem, or staying in a state of fear/stress/arousal.

CRADLE TO KINDERGARTEN

From the infant's birth to commencing Child Care and moving on to the school environment, development goes at a lightning pace. The range of tasks to be accomplished by the developing child are enormous: from developing day/night rhythms and patterns (circadian rhythm) to acquiring a basic moral code, learning how to negotiate and sustain friendships, and developing considerate behaviour.

The seeds of these tasks are there at – and indeed before – birth. We have broad genetic potential for development in all areas and what we make of this potential depends on our life experiences. We know that our brain develops and becomes organised in response to all the sensory stimulation it receives. Although we have developmental prime time or windows of opportunity, we continue to grow and develop all of our lives. We are very complex organisms and have a life long capacity to change and reorganise ourselves – this is what is meant in brain development terms by plasticity. This makes us both adaptive and responsive to our environment and experiences, whilst simultaneously vulnerable to the impact of our environment and experiences.

Although we demonstrate this plasticity, we know it is easier to do something right the first time rather than undo it and start again. This is particularly so when we consider human development. This is one of the reasons that there is such a strong focus on the early years of life and on providing the conditions for optimal development.

We look to the early years because experiences at the beginning of our lifespan establish a set of capabilities, orientations to the world and

[7] Shore, R (1997) *Rethinking the Brain, New Insights Into Early Development.* Families and Work Institute, New York. p18.

expectations about how things and people will behave that affect how new experiences are selected and processed. They form the blueprint or template for children against which new things are matched. Consider the following examples:

- The infant who has learned that she can engage an adult in play and who can successfully manipulate objects develops a fundamental belief in her ability to affect the world around her;
- The toddler who has learned that the people she depends on for comfort will help her when she is distressed develops trust, security and empathy;
- The child who has routinely curled up an adults lap for book-sharing is more likely to enter school with a keen interest in reading.

The child who misses these experiences may have a hard time recapturing them later in life. It will take a lot longer and will require more frequent and more intense repetition of experiences than it would for the infant. It means some 'unlearning' and re-learning rather than first learning. In short, getting off to a good start in life is a strategy for increasing the odds of greater competence and development to potential in adult life.

ZERO TO THREE: KEY TASKS

Most of us have a reasonable knowledge and understanding of theories of child development. There are many texts, theorists and developmental perspectives. Our challenge as early childhood professionals is to identify those early developmental tasks that – if mastered – appear to get children started along positive adaptive pathways. These same tasks, if seriously delayed or problematic for some reason, can cause a child to falter or to have developmental difficulties in one or more domain. When we review the research, child development texts and theorists, together with our accumulated knowledge and child development folklore , we see that these tasks cluster in three main areas of accomplishment across childhood:

- Negotiating the transition from **external to self regulation, including learning to regulate** emotions, behaviour and attention. This captures the child's emergence of self-control and independence.
- Acquiring the capabilities or building blocks that underlie **communication and learning.** This includes early language development, reasoning and problem solving.
- Learning to **relate to others** and form friendships. This highlights the emerging capacity to trust, to nurture and to solve conflict constructively.

These tasks are inter-related and begin with learning to self regulate.

ACQUIRING SELF REGULATION

WINDOWS OF OPPORTUNITY		
	Critical	Sensitive
Emotional	0-24 months	2-5 years
Motor	0-24 months	2-5 years
Vision	0-24 months	2-5 years
Early Sounds	4-8 months	8 months—5 years
Music	0-36 months	3-10 years
Thinking	0-48 months	4-10 years

Children move from helplessness to competence in terms of their regulatory capacity. This initially means mastery of tasks that were accomplished by the mother's body when in utero – but now must be accomplished by the child. These tasks include maintaining normal body temperature, organising and stabilising their biological rhythms of sleeping, waking, and feeding, and learning to soothe themselves and settle once their basic needs are met. As they grow and develop, it means constructively managing powerful emotions and keeping their attention focused.

Self-regulation cuts across all development. Living and learning requires people to react to changing events and experiences and to regulate their reactions. Infants and children are generally good at reacting – but need our help to learn to regulate themselves. The adult's first step in the earliest days of children's lives is to establish regulatory connections with them, and then to gradually shift the responsibility of regulation over to them in the day to day actions of sleeping, waking and soothing.

Developmentally, the first three months of life are a time of transition. The baby's behaviour and physiology shifts from inter-uterine to extra-uterine regulation. The full term infant of normal birth weight is well prepared to manage this transition – although there are wide ranging individual and cultural differences and variations in child rearing practices and expectations. The regulatory challenges of this period are greater for premature, low birth weight, 'at risk' or otherwise fragile babies. These children are those that fill our special hospital nurseries experiencing problems with many of the brain stem mediated body state/regulatory functions; for example, maintaining body temperature, respiration and steady heart beat.

The self-regulation involved in managing physiological arousal (e.g. hunger and thirst), emotions and attention are the earliest ways that infants and toddlers learn to manage themselves. They **begin** to acquire the behavioural, emotional and cognitive self control essential for competent life long functioning. We can see this demonstrated as they become more skilled in exercising self control, applying rules (e.g. Simon says), waiting, sharing, taking turns, concentrating and ignoring distractions.

3 ESSENTIAL CAREGIVING STRATEGIES

To best help children achieve the central tasks of childhood – developing self-regulation, acquiring the building blocks for communication and learning, relating to other people – caregivers need to ensure that the following three key strategies are integral parts of their care giving practice:

- the child forms a secure attachment with a caring adult,
- the environment is nurturing with minimal stress, and
- that appropriate multi-sensory stimulation is provided.

IMPORTANCE OF ATTACHMENT [8]

The last decade of research on the early development of children – particularly the 'brain research' – has resulted in a renewed appreciation and awareness of the importance of a secure attachment to the ongoing social, emotional and behavioural development of children. The best way to ensure the optimal development of children is to ensure that they have reliable care and support from the adults around them. Those first relationships between a baby and their parents are the most important of all.

We have also learned much about early brain development and the 'biology' of attachment through studies that have examined the impact of trauma, maltreatment and neglect and the consequences of insecure attachment.[9] We know that our capacity and desire to form emotional relationships is related to the organisation and function of specific parts of our brain.

Studies about caregiver-infant relationships show that the most powerful component of a secure attachment is early, sensitive care for children. This is characterised by:

- recognition that even the youngest infant can signal her needs and wishes
- accurate reading and interpretation of infant cues and signals
- letting the child's signals, rather than the parents needs or wishes, set the agenda and
- consistency or predictability over time.

The child's overall experience should be that her signals are effective in getting a response – that caregivers are available and willing to respond. In order to respond sensitively, a caregiver must

[8] See RUCSN Newsletter Issue 4 (2000) *It Begins With Attachment*.

[9] The work of Dr Perry and colleagues at the Child Trauma Academy, Baylor Medical Institute, has been very influential.

understand the cues and signals of the child, be willing to respond, and have the emotional strength and social support necessary to sustain sensitivity over time.

NURTURING LOW STRESS ENVIRONMENT

Play and exploration are crucial activities for young children. They help the child's brain develop in optimal ways. Child sensitive places, semi-structured activities and opportunities for exploration that are safe, nurturing and enriched with developmentally appropriate stimulation should be the core of all child focussed programmes. Play develops skills, but a child will only play when she feels safe. A child's sense of safety stems from a calm and predictable world – one in which she knows what will happen next. This means consistency across and within days, together with predictable routines. It also requires that the adults in this world are predictable, attentive, consistent, attuned and attached. We can make a child's world more predictable by having a daily schedule or routine that includes waking, eating, sleeping and bathing at fairly set times. We can also seek to keep significant changes to a minimum and recognise the impact that change has on the child's life. In an unpredictable world without routine, children become fearful and anxious. They do not feel safe and secure, they do not play, and they do not develop optimally. We should identify strategies to ensure that our care environments are places where children feel safe and happy.

YOU CANNOT SPOIL A NEWBORN!

- Consistent and responsive attention to the crying newborn will help the infant build in the neurobiological capacity to tolerate future stress in an optimal fashion.
- Newborns and infants should **never** be physically punished, hit or have food, affection or touch withheld. These actions can actually cause the brain to develop abnormally.

MULTI-SENSORY STIMULATION

A child's environment should also be rich in sights, sounds, smells, tastes and touches. Environments rich in sensory experiences stimulate the child's brain and give them new information about the world. For a child, a sensory-rich experience can be as simple as the smell of muffins baking, the feeling of a silky pillow against their cheek, or the difference between being outside in the shadow of the tree and then moving into the sunshine. It is important that caregivers realise the importance of early sensory experience – especially for the zero to three age group. Caregivers also need to be alert and recognise that too much stimulation can overwhelm a child causing stress and anxiety. One noisy toy with bells and whistles might be interesting, but too many noise-making toys might be over-stimulating. All children are different. In a group care environment, it is particularly important to get to know the children in order to appreciate and understand their developmental and tolerance levels. We also need to be aware that watching television is not considered to be a sensory rich experience for a child.

SUPPORT FOR CAREGIVERS

If you are having difficulties including all children in your care environment, consider discussing any issues and problems with your Regional Inclusion Support (SUPS) Team. They have a wealth of experience and are able to offer practical advice, suggestions and information about local resources. They can also help with information about referral procedures for children with additional needs. If you are unsure which SUPS Team covers your service, contact RUCSN. Inclusion Support Teams and RUCSN can offer staff training if skill enhancement is required.

This article was prepared by Lee Jeffery, Training and Resource Development Coordinator and was first featured in the RUCSN Newsletter Issue 1 2001. Any error, oversight or omission in attribution is regretted

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- **Focus on Zero to Three** (Part One) Issue 2 (2000)
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