Learning and the Brain

The developing brain: early childhood

All aspects of our adaptive life, including thought, perception, language, emotion as well as fine and gross motor skills, are mediated by the brain. A vast majority of the development disorders of childhood are attributable to some brain-related event. The human brain holds amazing mysteries, especially during the early childhood years. As neuroscience unfolds to inform us of some of its wonders, we come to realise how necessary it is to understand and apply this knowledge to our practice with children and young people.

At birth, the infant's brain already possesses all the neurons (the nerve cells) it will ever have! Unlike the other organ systems, which grow and regenerate their cells, the brain does not grow in the numbers of the neural cells that it has. What contributes to neural development and gain in brain weight in growth in the connections between the cells via the fibres, which literally sprout and reach out and touch each other. They establish links and networks that will expand and strengthen as the experimental repertoire of the baby expands.

Some neural connections are already 'hard wired', probably by the genes in the fertilised egg, allowing the newborn to regulate his breathing, heart rate and body temperature, and to manifest reflexes, all of which are necessary for survival. Other neural connections are awaiting the experience that will trigger the circuitry. The analogy between computers and the brain is quite well justified (although the most powerful computer known to man cannot come close to simulating the complexity of even a single nerve cell): at birth, the brain is like state-of-the-art hardware (nature): experience (nurture) is like the software that will bring about its functions, with nearly infinite potential.

Brain growth and growth spurts

The brain reaches 70% of its adult weight by 2 years of age, nearly 90% by age 6, and its full weight by puberty. It consumes twice as much glucose, the brain's source of energy, as the adult brain from age 4 until about puberty. Researchers think that young brains are as primed as they will ever be to process new information.

There 'appears to be a relationship between the rate of brain growth and children's ability to learn. Epstein (1980) suggests that the brain growth spurts occur from the ages of 3 to 10 months, 2 to 4 years, 6 to 8 years. 10 to 12 years and 14 to 16 years. Interestingly, these periods are claimed to be most opportune for learning, this does not suggest that learning will not take place at other times. This "theory has some educational implications, which are being trialled in some schools in the USA.

Critical (sensitive)

In the course of early development, specific (critical periods of time seem to mark most receptivity and sensitivity to certain environmental stimulation. If these windows of opportunity are not property provided for in the most impressionable times, the young brain seems to have difficulty achieving that function. The critical periods seem to be in evidence for most domains of development.

- In infants, neuronal growth spurts in the visual cortex, seem to occur between 4 to 8 months. Example: if a baby is born with cataracts that are not removed by 2 years of age, he may become cortically blind.

- Prolonged periods of reduced linguistic input in early childhood affects the development of language. The most poignant example is that of Genie (Curtis1977), a child kept in severe isolation until she was discovered at age 13. She subsequently failed to develop but a rudimentary language system despite intensive remediation efforts.

- Links between conductive hearing loss associated with chronic middle ear infection and language delay are clinically well established.

- Intermittent conductive hearing, loss and attention deficits and learning disabilities seem associated (Adesman, Altshuler, Lipkin and Wallace, 1990).

- Attachment, where the infant forms mental representations for his affections towards his mother or other primary carers in the first year of life also seems such a time-dependent construct (Myers, 1987).

- Providing a child with calm and comforting physical affection can strengthen the immune system and have an effect on the brains long term stress regulating systems (Sunderland, 2006)

- Parental neglect, abuse, indifference or severe discipline seems to alter the circuitry in the prefrontal lobes in young children, affecting their emotional response style (Davidson, 1994).

- Restriction of movement in the early years seems to prohibit the synaptic connections in the cerebellum. A child immobilised in a body cast until 4 years of age would learn to walk eventually, but never smoothly (Greebough, 1996).

Early intervention: nurture leading nature

The insights gleaned from neuroscience reaffirm the effect of early intervention in children to accomplishing age-appropriate adaptive behaviours. However, the lasting benefits of these early interventions seem to be dependant on the time in development in which enrichment is introduced.
Follow up studies on Head Start, a major pre-school early intervention project in the USA, indicate that the initial IQ gains made by participating disadvantaged children do not seem to last, although they tend to show better school adjustment than their peers (Zigler and Styfco, 1993).
In a tightly controlled investigation of another early intervention and enrichment program (Abecedarian Project), however, the group that participated in the enrichment program from infancy (6 to 12 weeks of age) did not show an erosion of the IQ gains made after the intervention, maintaining the benefits (Campbell and Ramey, 1994). In this investigation, the children who were provided with enriched experiences after 5 years of age did not sustain any benefits compared with their controls.

Hemispheric specialisation

In the fully grown brain, the 2 cortical hemispheres have specialised functions:

- The left hemisphere typically processes and responds to verbal information, attends to logical-mathematical, analytical tasks, and is credited with the ability to organise and process sequential material.

- The right hemisphere, on the other hand, is typically said to process stimuli in a holistic manner, to analyse and decipher spatial visual clues and to be sensitive to the melody and other musical, rhythmical aspects of the information received, analysing it simultaneously (Springer and Deutch, 1984).

Folk psychology tends to attribute the more logical,. analytical qualities of the left hemisphere to masculine, and the more visual, melodic, intuitive qualities of the right brain to feminine characteristics. But, as in life, these characteristics cannot survive on their own merits; indeed they are complementary, and need each other to be able to make the best sense of the world.

The 2 areas responsible for speech and language processing are typically located in the left hemisphere. The hard-wiring for this specialisation may be present from the very early months of infancy. However, the functional specialisation for language processing in 1 hemisphere shows a developmental progression. No hemispheric preference was found in visual and auditory language processing in 3 year old children, although a preference became progressively stronger in 6 and 9 year olds. By 12 years of age, hemispheric asymmetry (lateralisation) was found to be strongly established (Talay, 1978).

Hemispheric dominance and hand preference

Hand preference in young children is usually evident by school age. Traditionally, there has been an association between right-handedness and left-hemisphere dominance.

Hand preference does not seem to have any bearing at all on the adaptive and learning styles of young children. except in cases where mixed (unclear) laterally Is observed. Mixed dominance where a child may exhibit right-hand but left-foot preference. no preference between hands (ambidextrality and difficulties in crossing of the midline with either hand or foot, are often reported in clinical investigations of children with learning difficulties.

Hemispheric preference versus cooperation

Learning or cognitive styles observed in children perhaps reflect their preference for neural circuits that are better established or the hemisphere that tends to exert a stronger influence. However, cooperation between these structures with different processing styles results in optimal efficiency. Furthermore, stimulating 1 hemisphere may result in a facilitated processing ability in the other.

Development of the Brain

The Basics

As you read the words on this page, you are utilizing thousands of the 100 billion (more or less) nerve cells that make up your brain. The electrical firings and chemical messages running between these cells, called neurons, are what produce our thoughts, feelings and interactions with the world around us

- There are between 80 and 100 billion nerve cells, or neurons in the average human brain.
- Each neuron may make between 1000 and 10,000 connections with other neurons.
- There are more possible ways in which the neurons of a single human brain can be interconnected than there are leaves in a rain forest.
- The development of 'connections' accounts for the increase in brain weight after birth.
- The brain reaches its maximum weight by about 20 years.
- The average male adult brain weighs 1375 grams (about 3 pounds), and the average female brain weighs 1250 grams.
- When full grown the brain loses around 1 gram per year.

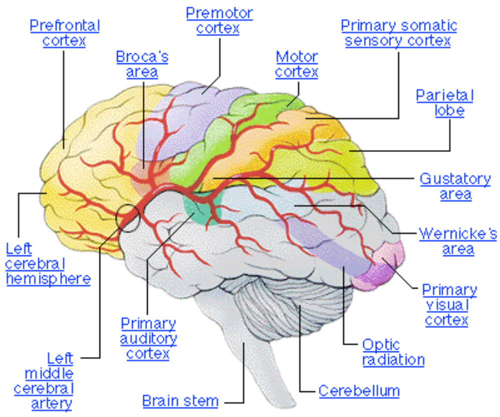
Major structures of the brain

Cerebral hemispheres (or cerebrum)

The cerebral hemispheres are the 2 largest structures at the top of the brain which enfold most other brain structures. The top layer of the cerebrum is called the cerebral cortex. It is winkled. When outstretched the cortex's surface area is around 2.5 square foot. The cortex is pinkish-grey in colour on the surface, and white below (around 1 cm, below).

The hemispheres are basically symmetrical and can be described in terms of 'lobes'. There are 4 lobes:

- Frontal
- Parietal
- Occipital
- Temporal



A large crevice running along the cerebrum from front to back (longitudinal fissure) divides the 2 hemispheres. The tissues within this crevice provide a bridge between hemispheres. This band of tissues is called the Corpus Collosum. Two further fissures are natural dividing lines. They are called the lateral fissure and the central fissure.

The visual cortex lies at the back of the cerebrum. Voluntary movements of muscles are controlled by the motor area. A motor strip appears in both hemispheres. Sensory experience and body sense is controlled by the somatosensory area. This area deals with heat, cold, touch, pain and sense of body movement. The auditory area lies on the surface of the temporal lobe at the side of each hemisphere. This area decodes auditory signals and patterning of sound, i.e. human speech.

Pruning ('apoptosis')

Neurophysiologists have identified an initial burst of synapse formation in the first month after birth, followed by a pruning of synapses in all areas of the brain. This process seems essential because initially there are many more connections than necessary and this abundance creates many redundancy pathways. Experience seems to erase some of these connections and strengthen the necessary ones in the wiring diagram. Interestingly, pruning appears to occur in tandem with the developmental process. The maximum density of synapses in the areas of the brain responsible for language comprehension and production occurs at about 3 years, while the cortical cells responsible for vision are maximally dense at 4 months of age, with rapid pruning thereafter (Huttenlocher, 1994).

It is intriguing to note that the combination of an early surge of synaptic growth followed by pruning, or canalisation, means that the 1 year old actually has denser synapses and dendrites than the adult. Pruning continues throughout early childhood into adolescence.

Neuroscience and early childhood education

Recent developments in the field of neuroscience have helped us sharpen our appreciation of the windows of opportunity presented in early years.

- Second-language learning is easiest in early childhood, a common observation not often followed in educational practice.
- Right and left hemispheres can be prompted to work in tandem: music seems to excite the innate circuits, enhancing complex reasoning and maths skills.
- Emotional tonality set in infancy may assist in or hinder a child from self-regulating at later stages. It also seems to affect the ease with which the child adapts and interacts in a learning environment.
- Teaching young children to visualise as they listen to verbal material may enhance their comprehension of language and serve as a safety net in language-related learning disabilities.
- Better understanding of hemispheric preference and learning styles may have a significant impact on facilitating young children's cognition.
- The role of early intervention, or environmental enrichment and stimulation in the growth and development of the at-risk child, from the first few weeks of life, seems central to sustained positive results.
- Interdisciplinary collaboration between neuroscientists, child development specialists and educators is an essential step towards uniting theory and practice with young children.

How do neurons work?

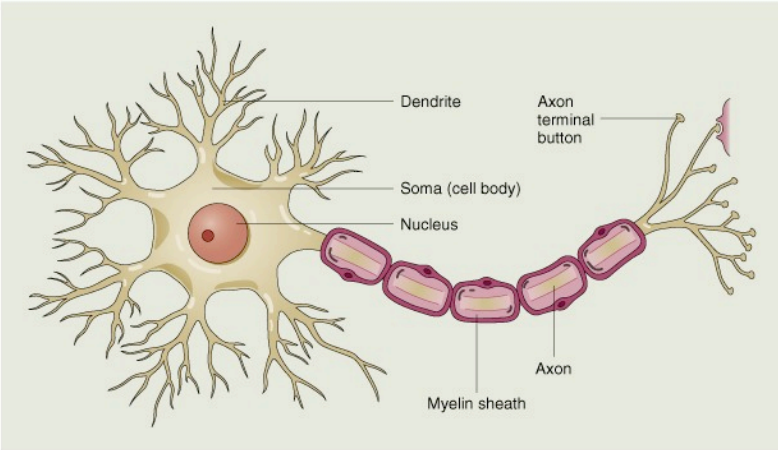
Neurons are the building blocks of the central nervous system CNS. Glial cells are other kinds of cells found with the CNS. They are more numerous than neurons and smaller. They supply nutrients and structural support to neurons and provide a barrier to certain substances from the bloodstream. About 80% of all neutrons are found in the brain, in particular in the cerebral cortex, the topmost outer layer. Information is passed from neuron to neuron in the form of electrochemical impulses; these constitute the language of the nervous system.

There are 3 main kinds of neuron.

Sensory- which carry information from the sense organs to the CNS.
Motor· which carry information from the CNS to the muscles.
Connector - which connect neurons to other neurons. Connector neurons are the most numerous and constitute about 97% of the total number of neurons found in the CNS.

Although no 2 cells are identical, they share the same basic features:

a cell body
cytoplasm
dendrites
axon
myelin sheath
nodes of Ranvier
synaptic vesicles - which contain neuro-transmitters
synaptic cleft.



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The effects of neurotransmitter activity can be excitatory or inhibitory. There are thought to be over 30 different kinds of neurotransmitter although their exact function is not known.
The more a neural pathway is used at an early age the thicker the myelin sheath around the nerve and more robust the neurological connection – it is a matter of use it or loose it!

Common disorders associated with CNS structures
The disruption of or damage to a structure often illuminates its function, although the complexity of the networks within the brain may make such conclusions tentative. The common disorders of the CNS given below may assist you in bringing together some structures and their functions.

Spastic paralysis or spasticity. Associated with damage to the pyramidal motor system (primary motor area in the frontal lobe) or its tract, resulting in abnormal muscle contractions and inability to perform voluntary move, movements freely and smoothly.

Atbetosis. Associated with damage to basal ganglia and other extrapyramidal structures, resulting in uncontrollable writhing head, arm and hand movements, particularly with volitional activity.

Ataxia. Associated with damage to the cerebellum, resulting in easily lost balance and wide gait of the legs, or inability to perform finely tuned motor acts such as reaching out to hold an object.

Extrapyramidal disorders. Associated with disorders of the extrapyramidal motor system, resulting in abnormal movement patterns, such as Parkinson's disease (involuntary tremor and rigidity) or Huntington chorea.

Multiple sclerosis. Associated with gradual disappearance of the myelin sheath coating the axons, making efficient movements difficult and often resulting in confinement to a wheelchair.

Cardiovascular accident (CVA, or stroke). Associated with bursting of a blood vessel and deprivation of oxygen to the brain tissue, resulting in varying degrees of brain damage, from paralysis (usually on one side only), to loss of speech and language; effects can be transient or 10ng';lasting.

Expressive aphasia. Associated with damage to Broca's area in the frontal lobe, resulting in difficulty planning and executing sequential speech movements; in severe cases, inability to talk.

Receptive aphasia. Associated with damage to Wernicke's area in the temporal lobe, resulting in difficulty comprehending verbal language and responding appropriately.

Cortical blindness. Associated with damage to the occipital lobes, resulting in inability to see or to interpret visual images, despite normal vision and intact visual nerves.

Polio. Associated with a virus that destroys the motor cells in the spinal cord, resulting in flaccid (hypotonic; no muscle tone) paralysis below the level of the lesion (cut; damage).

Spinal injury. Associated with accidents, bullet wounds or sports injuries. The resulting damage depends on the level of the disruption to the cord; the higher up towards the head it is, the more extensive the damage, as no sensory information coming from the neck down can reach the cortex and no motor impulses directed .to areas below the neck can reach the muscles.

Spina bifida. Associated with that birth defect where the spinal cord has failed to close properly; in most severe cases, spinal nerves will be outside the spinal column in a sac, usually in lower spinal levels. Youngsters with the disorder may exhibit flaccid paralysis and no sensation from the body, from the level of the lesion, down. Muscles that do not receive any innervation gradually waste away or atrophy.

Hydrocephalus. May be associated with spina bifida, which disrupts the circulation of the cerebrospinal fluid; it may also be caused by congenital abnormalities, or meningitis, an infection of the protective membranes of the CNS.

At this point, it is important to state that disruptions of the infinite cortical and subcortical networks are just as likely to contribute to atypical behavioural outcomes as are localised lesions. Many developmental disorders are not necessarily associated with a clear-cut site on the brain that is responsible for the dysfunction, although they may have neurological bases.

Attention deficit hyperactivity disorder (ADHD). Has been associated with abnormalities in the reticular activating system (which regulates attention and arousal of the cortex by selectively screening perceptual input), and prefrontal lobe lesions (Lou, Henriksen and 8ruhn, 1984).

Dyslexia. Reading difficulties may involve both auditory and visual processing mechanisms (Duffy, Dencia, McAnulty and Holmes, 1988).

Auditory processing disorder. Associated with parietal temporal dysfunction, resulting in difficulty comprehending oral language, it may be reflected by measures such as difficulty following directions or learning new vocabulary items.

Visual processing disorder. Associated with parietal occipital dysfunction, it may result in difficulty deriving meaning from visual stimuli, making visual interpretations, or reproducing visual forms.

Autism. There is near-consensus that this autism is caused by neural aberrations; among the findings are cerebellar and prefrontal and temporal lobe abnormalities and various neurotransmitter disturbances (Nelson, 1991).

Wernicke-Geschwind Model

Broca's area appears to store articulatory codes that specify the sequence of muscle actions required to pronounce a word. When these codes are transferred to the motor area, they activate the muscles of the lips, tongue and larynx in the proper sequence and produce the spoken word.

Wernickes area is where auditory codes and the meaning of words are stored. If a word is to be spoken, its auditory code must be activated in Wernicke's area and transmitted by a bundle of nerves to Broca's area, where it activates the corresponding articulatory code. In turn the articulatory code is transmitted to the motor area for the production of the spoken word.

If a word is spoken by someone else is to be understood, it must be transmitted from the auditory area to Wernicke's area, where the spoken form of the word is matched to its auditory code, which in turn activates the word's meaning.

When a written word is presented, it is first registered in the visual area and then relayed to the angular gyrus, which associates the visual form of the word with. its auditory code in Wernicke's area; once the word's auditory code has been found, so it has its meaning. Thus the meaning of words is stored along with their acoustical codes in Wernicke's area.

Angular gyrus matches the written form of a word to its auditory code. (Neither Broca's area or the angular gyrus store information around word meanings).

The meaning of a word is only retrieved when its acoustical code is activated in Wernickes area.

Recent research by Uta Frith appears to indicate that people with specific learning difficulties may have left hemispherical damage in these areas, particularly damage to the neural pathways which relay messages to and from localised sites.

Emotional Intelligence

Our genetic heritage dictates our emotional temperament, however our temperament involves brain circuitry that is malleable, and therefore our genetic temperament is not our destiny. The emotional lessons that are provided by nurture are introduced and reinforced by significant others in our lives at all times but particularly In our early years i.e. home, school etc .
Our formative years and adolescence are time critical periods for establishing our emotional circuits. These circuits are the hard wiring of our emotional habits. This emotional shaping is exhibited in our ability to be adept or inept at the basics of emotional intelligence.
An awareness of emotional intelligence provides people young and old with the ability to display and verbalise the processes of self control, enthusiasm, persistence, self motivation, self belief, self worth and above an self esteem. All behaviours are learnt. Therefore all of these skills can be taught!

The most opportune time to embark on these lessons for life is in the formative years. If this early opportunity is missed the learning of these skills can still take place throughout our lives. Established behaviours will take significantly longer to modify enabling individuals to acquire new emotional circuits and habits. An awareness of our own emotional intelligence can provide us all with an opportunity to use these learnt behaviours and intellect to over ride the genetic lottery we have inherited.
A recent survey of parents and teachers show a worldwide trend for our present generation to be more emotionally troubled than the last, these young people appear to be more lonely, depressed, angry, unruly, nervous, impulsive and aggressive.
(Goleman 1995)

Emotional Hijacking

"Anatomically the emotional system can act independently of the neo cortex". "Some emotional reactions and emotional memories can be formed without any conscious cognitive participation at all." (LeDoux 1995)

Our fight or flight reflex is housed in our cerebellum at the base of our brain.
This response is triggered by our memory systems based in the limbic system sending out an emotional response message.

Signals are transmitted from the senses i.e. visually through the retina to the thalamus (limbic system), where it is translated into the language of the brain. Most of the message is then sent to the visual cortex, where it is analysed and assed for an appropriate response.
If that response is emotional a signal will then be passed to the amygdala to activate the emotional centres.

Joseph LeDoux's research has shown that a small portion of this signal will be transmitted straight from the thalamus to the amygdala. This takes place before the cortex is involved triggering an emotional response before rational cortical processing can take place. LeDoux refers to this as a "quick and dirty process".

When this is triggered the hippocampus (our store of facts without emotion) triggers a biological response this links back to the amygdala (our bank of emotional memories and reactions) for an appropriate response to take place. This response is referred to as an emotional hijacking.

This response is thought to take place at almost twice the speed of the "normal route" and our responses are dictated by raw emotion until the cortex is engaged.

This would suggest that we have two inherent memory systems within the limbic system, the hippocampus for ordinary facts and the amygdala for emotionally charged ones. Example: our hippocampus is crucial in recognising a face, the amygdala adds whether we like the person or not. This means we may well not be thinking rationally or engaging the higher order thinking and therefore making 'rational' decisions which may manifest themselves as challenging, and sometimes, unsafe behaviour.

We, as Forest school leaders, need to understand how the brain processes information and emotions and by working with self esteem and emotional intelligence we are enabling learners to feel confident and relaxed and they are more likely to enter into the cortex and higher order thinking more willingly.

Conclusion

We have taken a bird's-eye view of a complex and often underscored field of study in early childhood through to adolescence - the human brain and its developmental properties. The implications we draw from it make it imperative that we incorporate this knowledge in our understanding of and practice with children and young people. The field of neuroscience and child development (developmental neuroscience) will probably continue to challenge our thinking and expand our horizons in the years to come. Theirs is a promising partnership!

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