What About The Children?

RESEARCH SUMMARY

Brain Development in Young Children

1. **How the Timing and Quality of Early Experiences Influence the Development of Brain Architecture. (2010)**
   Fox, S.E., Levitt, P. & Nelson, C.A.
   Child Development, 81 (1), 28-40.

2. **Mapping Prefrontal Cortex Functions in Human Infancy. (2013)**
   Grossmann, T.
   Infancy, 18(3), 303-324.

The development of human brain architecture is not a fixed process like the building of a car by a pre-programmed robot. Patterns of brain development are modified substantially by experience in infancy. In essence, the wiring diagram of the human brain is not entirely fixed by our genetic framework. Environmental factors play a crucial role in developing the wiring patterns within a local brain region, and between brain regions, of an infant. Once formed, these wiring patterns are to a large extent retained beyond infancy into adult life. The growth of new neurons, and the attendant circuitry in the developing infant brain, is controlled by a large range of chemicals. These are transcription factors (molecules that control how the genetic code in a cell is read and triggered to produce specific proteins for growth), and axon guidance molecules that enable a growing nerve fibre from one neuron to be guided to its target neuron elsewhere either within a specific brain region, or to a different brain region (i.e. a long distance circuit connection). If this molecular guidance system is modified by environmental effects, atypical connections may be made and normal function can be disrupted. In mankind, this developmental stage of brain architecture occurs in the first three years of life.

Paper 1 For legal reasons, invasive experiments on the developing brain structure of infants are prohibited. However, it is possible to perform experiments on animals to explore the effect of environmental changes. A well understood set of neural pathways is the development of the visual system in kittens. Kittens reared with a normal visual experience (seeing with both eyes) made normal connections in layer iv of the striate cortex and both eyes were connected to all neurons there. However, if sight in one eye was experimentally occluded at birth for a limited period of time, that eye became functionally blind. The closed eye had not been able to make connections to layer iv. That environmental change, due to light deprivation in one eye, disrupted the local brain architecture with lasting consequences. An analogous effect was found in human babies with congenital cataracts. These led to difficulties in face processing even after removal of the cataracts in the first few months of life. A more subtle visual effect could be induced by showing newborn monkeys either only monkey faces, or only human faces. The monkeys could only discriminate between the facial type that they had been exposed to; i.e. if they had seen only human faces, they could only discriminate between human faces and not monkey faces. These types of experiments on vision have led to the discovery that there are time-related effects to environmental exposure. ‘Sensitive’ periods are times in development when the brain is responsive to an environmental experience in forming patterns of activity. ‘Critical’ periods are times when an environmental change produces an irreversible effect.

Paper 2 The importance of 'sensitive' and 'critical' time periods was examined in detail during the first postnatal 12 months of human life in one brain region – the prefrontal cortex (PFC). The prefrontal cortex is the anterior part of the frontal lobes of the brain (the part of the brain near the forehead). The PFC occupies roughly 1/3rd of the cortex. It can be crudely divided into the medial PFC (mPFC) and the lateral PFC (lPFC). The lPFC has both left and right components. The mPFC makes connections to other parts of the brain involved in emotional processing and memory. The lPFC is connected to areas of motor control and performance-monitoring parts of the brain. In human infants it is possible to measure brain activity non-invasively by using functional near-infrared spectroscopy (fNIRS). The equipment consisted of a bonnet-like cap placed on the infant's head containing surface probes to record brain activity, usually in response to a visual or auditory stimulus. The objective of the study was to assess when changes in the PFC could be identified with a variety of different stimuli.

Olfaction (smell of the mother's own colostrum) occurs in the newborn and activates the left mPFC; this response decreased with age after the child had learned breast-feeding.

Newborn babies rapidly acquire auditory responses to speech. Infant-directed speech (IDS), adult-directed speech (ADS), emotive speech and monotone speech was processed in the mPFC, whereas syllable sequences with different repetition patterns were picked up in the left lPFC. Infants had a greater propensity for processing IDS compared to ADS; this suggests that the infant preferentially processed IDS which was relevant to the infant's affect response to the mother. Similarly the infant positively processed even non-maternal emotive speech compared to monotone speech in the mPFC. This relates well to emotional prosody (sing-song voice) that stimulates the mPFC in newborns.

At 3 months, auditory processing of speech and language perception predominated in the lPFC and was handled differently depending on whether the infant was awake or asleep. Infants could discriminate between forward speech (normal speech) and backward speech (a reversed recording) as the right lPFC responded more to forward speech when the infant was awake rather than when it was asleep. Furthermore, if a beep sound was given to precede a female voice so that the beep became predictive of the female voice, or in a control experiment with different infants where the beep was not associated with a female voice, lPFC activity was only found if the beep was predictive of the female voice. This experiment indicates that the lPFC is involved in auditory working memory and learning.

At 4-13 months the infant can distinguish between the voice of a mother or a stranger, both in IDS and ADS. This response was found both in the mPFC and left lPFC.

In summary, the PFC shows time-dependant sensitivity to the development of auditory perception with initial recognition responses in the mPFC. Over time these responses are linked to the lPFC where memory and learning take place. This conjunction of the two processing centres seems to be correlated with early affect responses of the young infant to its primary carer.

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