The importance of experience prenatally and in the first two years of life:

A NEUROBIOLOGICAL PERSPECTIVE

In a two-part article, **Daniel Isaacs** explores the importance of early experiences, focussing in this first part on the relationship between 'normal' experiences and subsequent neurobiology and biochemistry.

As a foetus and then an infant, we are subject to the experiences that our environment affords us. Our brains grow and adapt to the circumstances in which we are born in order to ensure that we can survive; this is called experience dependence[1]. These experiences may also interact with the genes we have inherited and can initiate or inhibit potentials for development of one kind or another[2]. As such, there is an important relationship between our biology and our environment, between nature and nurture.

This article will explore the relationship between 'normal' early experiences and biochemistry and brain development, and investigate the consequential developmental trajectory. More specifically the article will focus on the hormones oxytocin and cortisol, and the development of brain structure; particularly the social brain in relation to social experiences and attachment.

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Chemical reactions to experience

Oxytocin

Oxytocin is a feel-good hormone. It is in part responsible for the good feelings we have during sex and when we are close to those we love. It boosts our immune system and helps protect us from pain. It is also released in large doses in both mother and infant during childbirth and it helps to induce labour[1].

One very important function of oxytocin is the facilitation of parent-infant bonding[3]. An increase in prenatal oxytocin has been associated with enhanced postnatal bonding[4]. Additionally, the relationship between mother-infant interactions immediately after birth and oxytocin is important. The breast crawl is a remarkable sequence in which the newborn infant, if left uninterrupted on the abdomen of the mother, slowly makes its way to the breast and begins to suckle. Suckling within the first few hours of life leads to an increase in oxytocin in both the infant and mother's brain. This stimulates the production of gastrointestinal hormones that support absorption of nutrients in the infant, and leaves the mother with feelings of increased love for the infant. Each time the infant breastfeeds more oxytocin is released. This further enhances the early mother-infant bond[5]. In support, it has been found that mothers are more likely to keep their infants 100 minutes longer every day if the infant suckles within the first hour of life, in comparison to mothers whose infants do not[6]. This appears to be indicative of a reduction in the risk of abandonment, as a function of early infant-mother experiences.

Cortisol

Cortisol is a hormone that is released when stress is high. Maternal prenatal cortisol can cross the placental wall and interfere with the foetus. This can cause detrimental effects such as destruction of brain cells[1].

Talge et al[7] found that the structure and function of the foetal brain can be altered by high levels of antenatal maternal stress, and can predispose the child to risk of developing subsequent mood and anxiety disorders. Furthermore, if mothers show heightened stress and anxiety 12 to 22 weeks into pregnancy then there is an increased risk for behavioural problems

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such as ADHD later in childhood[8]. This implies that at particular sensitive moments of foetal development increased cortisol may have a more substantial effect; this has been called a programming effect[9].

Despite the apparent pernicious effects of cortisol, a recent study has found that the effect of high cortisol in utero on cognitive development can be moderated by the quality of the mother-infant relationship[10]. These findings were groundbreaking and suggest that the infant's early environment and relationship with the primary care giver could eliminate the pernicious effects of cortisol. This underlines the importance of good early experiences, and the interaction such experiences can have with certain chemicals in the brain and body.

Therefore, there is an important interaction between experience, pre- and postnatal biochemistry, and the development of the parent-infant bond, as well as the risk of the onset of emotional, behavioural and psychopathological difficulties. This highlights the nature-nurture interaction.

The social brain and experience

The new-born baby is equipped with a primitive brain; the reptilian brain, which includes structures such as the brain stem. It is responsible for basic functions such as breathing and heart rate, as well survival responses such as fight, flight or freeze. The mammalian brain, otherwise known as the limbic system develops on top of the reptilian brain and is responsible for emotions, moods and emotional memories. The amygdala is an important mammalian structure. Finally, the neocortex, which develops predominantly postnatally, is responsible for cognition, reasoning and other higher order functions[11].

The brain contains on average 100 billion neurons, with each connecting directly to 10,000 others, communicating via 100 trillion synapses[12]. These are all present at birth, but which neurons connect to which is dependent upon experience. The connections and synapses that are not used, as a result of the infant's experiences, are pruned. In contrast the cells, connections and synapses that are wired remain so, and result in an infant's experience being processed through these connections over and over. This leads to expectations about the outcome of previously experienced situations[1]. The last trimester and the first two years of life are incredibly important for the development of the brain, with 250,000 cells produced every minute in the foetal brain. This is thought to be a sensitive period[1].

The social brain

The social brain, more specifically the right hemispheric orbitofrontal cortex, is extremely experience dependent. Gerhardt[11] claimed that this was so that the infant can adapt themselves to their specific environment. Social interactions and communications such as looks and smiles have an important part to play in the development of this part of the brain. Positive looks from the parents to the infant communicate positive arousal in the parent, which initiates positive arousal in the nervous system of the infant. This triggers the release of beta-endorphin and dopamine which make their way to prefrontal regions, providing a good feeling for the infant. This also initiates an increase in glucose uptake in the prefrontal cortex, which stimulates this region to grow[13]. The infant stores these images using connections between the orbitofrontal cortex and temporal lobes. The images are referred to in times of need, as a form of regulation and security[11].

Secure infants are able to explore the world, as they have a reliable and responsive caregiver to turn to in times of need. Ambivalent children closely monitor their caregiver, as the caregiver is often inconsistent and unreliable. Avoidant children experience an unresponsive/unavailable caregiver and so turn off their attachment system.

Attachment and the brain

The infant that experiences positive early social interaction with an emotionally attuned caregiver that regulates their states is likely to be securely attached[14]. Attachment classification stemmed from the seminal work of John Bowlby[15], who postulated Attachment Theory. He hypothesised that the infant strives to ensure survival and security by maintaining close proximity to the caregiver. In development, Ainsworth postulated three categories of attachment that represent an infant's way of relating to their caregivers: secure; insecure ambivalent; and insecure avoidant. She assigned infants to one of these categories based on the Strange Situation test, which investigated how they managed being separated and reunited with their mother. She posited that the infants internalised their experience of relationships and these strategies for relating, and these formed internal working models of relationships in the infants mind.

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Canterbury and Gillath[16] found neuropsychological evidence for these strategies and internal working models. In response to a primed sense of security, ambivalently attached individuals showed significantly greater activation in emotion and perception processing regions of the brain, suggesting a more intense emotional response and difficulties regulating this, which seems to indicate the aforementioned monitoring behaviour. Avoidant-attached individuals showed increased activation in memory processing and retrieval regions, regulatory and social processing regions, a correlation with activation in regions responsible for processing salient or aversive stimuli (amygdala and insula), and with regions involved in reward processing. Such widespread activation suggests great arousal in response to security. Such stimuli would be in contrast to the aforementioned unavailability of the caregiver, and so likely be very arousing. However, again we must consider methodological limitations of this study. The sample size was small (N=30) and therefore one must be careful drawing inferences from the results.

The focus here has been on mothers; however, the experience an infant has with their father is also very important. Whilst research with fathers is not as prolific, one study found that there was no clear difference in attachment security to fathers in comparison to mothers[17], and it has also been suggested that, biologically, fathers are no less sensitive to the infant[1].

In sum, we can see that positive and negative social experiences in the first two years, with both the mother and father, play a vital role in the development of the social brain, and subsequently in social functioning of the infant, again emphasising the interplay of nature-nurture.

Conclusions

This article provides a brief insight into the relationship between early experience and neurobiology, and is by no means a comprehensive review of the literature. However, it is evident that the experiences we have prenatally and in the first two years of life have a significant impact upon our developing biochemistry and neurobiology. In turn, this has implications for the developmental trajectory; more specifically, social, emotional and behavioural functioning, and the risk of developing psychopathology.

Good experiences in the formative years can increase oxytocin, decrease cortisol, facilitate the development of the social brain and enhance parent-infant bonding and attachment, and subsequent development. However, the development of the brain can be altered by undesirable and detrimental experiences, such as trauma and maltreatment. In turn this can lead to increased risk for developmental difficulties and psychopathology. This will be the focus of the second article.

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