RESEARCH SUMMARY

Neurohormones and temperament interact during infant development
Jones, N.A. and Sloan, A. (2018)
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The idea that each individual has a characteristic pattern of response and behaviour that is relatively consistent during his or her lifespan – a temperament – has a long history, going back to the 'four humours' of classical times. In modern psychology, temperament is considered to be physiologically based, to be largely independent of learning, and to set the trajectory for an individual's development through infancy to childhood and beyond. It is now believed that temperament development begins before birth. Many theoretical models have been produced that set out how environmental factors, including stress and sub-optimal parenting, may interact with genetic and physiological ones to influence the development of a baby's temperament. In recent years, the concept of 'environment' in some of these theories has been expanded to include the environment of the growing baby in the womb, which has the potential either to confer a protective function or to increase risks.

In this extensive review, Nancy Aaron Jones and Aliza Sloan from the Department of Psychology and Behavioral Neuroscience at Florida Atlantic University, Jupiter, Florida, USA examine theories and related research by their own group and others that link individual differences in physiological development and in the interaction of hormones in the brain with the development of temperament before birth and in early infancy. Their survey includes studies in normally developing infants and in those at risk due to excessive environmental stress. Studies of two hormones, cortisol (known colloquially as the 'stress hormone') and oxytocin (the 'cuddle hormone') form the backbone of the review.

Jones and Sloan describe how recent research has revealed that, although temperament itself is a stable feature of each individual that is seen to emerge in early infancy, the relationship between the physiological and environmental factors from which it does emerge is a complex and dynamic one. The range of possible combinations of biological factors – genetics (including the parents' genetics), physiology and hormones – with behavioural and environmental ones is immense, and a complete understanding of how temperament emerges can only be achieved with a multi-disciplinary approach.

The authors present a table of six theoretical models that have been suggested for the interaction of these disparate factors in the development of infant temperament. Some of these focus on normally developing infants, and others on those in whom stress or other factors present significant difficulties. They suggest that each of these models adds important insights into the relationship between stress, brain biochemistry and

emerging temperament, but that they are not opposing or even completely distinct and that a greater understanding can be obtained from a knowledge of them all.

They then unpack the concept of 'temperament' in infancy further, explaining that it can be broken down into two key components: reactivity, or the quality and intensity of infants' response to external events, and regulation, or their ability to modulate and control this emotional response. Variation between individuals in both these characteristics is very large. At the extremes, some infants and children show hardly any reaction to changes in their environment (behavioural inhibition) while others have extreme reactions (exuberance). Reactivity can be assessed by measuring nervous system activity and hormonal levels as well as by observing the infants' and children's behaviour.

The second basic component of temperament, regulation, begins in early infancy as newborns learn to control their emotions by, for instance, averting their gaze or crying to alert their care-givers. This is not completely innate to an individual and can be acquired; research suggests that the quality and sensitivity of the care given to an infant strongly affects how it develops. Regulation continues to develop through the early school years, as the frontal cortex continues to mature and – at least in normal development – the growing child's concentration and emotional control improves. Infancy, however, is the crucial period for regulation development, and excessive stress in babyhood can lead to poor development of regulation and an increased risk of mental health difficulties in later childhood and beyond.

Successful intervention with this process to reorganise a young child's temperament and minimise these risks will require a detailed understanding of the interplay between environmental features and physiological ones – and specifically, hormones in the brain – that affect temperament as it develops. Jones and Sloan set out our current understanding of these processes. More than 15 hormones are known to have some effect on foetal and infant development. These have been extensively researched in recent years, although 'paradoxically', as the authors noted, most studies have concerned abnormal development. For example, several groups' research, including their own, have shown that infants of depressed mothers tend to have high levels of the hormones cortisol and norepinephrine, and low levels of serotonin and dopamine.

Much of the rest of the review focuses on the roles on the two hormones thought to be most important for the development of infant regulation and temperament: cortisol and oxytocin. Stress activates the three glands that make up the hypothalamic – pituitary – adrenocortical axis (HPA axis), which initiates a cascade of biochemical responses leading to the release of cortisol from the adrenal gland. Hormonal responses to maternal stressors can be measured in the foetus, and the system is well developed by the time that an infant is born. However, the characteristic diurnal pattern of cortisol release that is seen in children and adults is not present in young infants. The biochemical response to short periods of moderate stress in infancy is thought to have a protective effect on the developing brain. However, if stress is constant or severe enough for the HPA axis to be unable to return to its 'unstressed' state, the axis will become dysregulated and the normal pattern of cortisol release will not emerge. Stable breastfeeding patterns and skin-to-skin contact between mother and infant

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(such as the so-called kangaroo care approach) will aid the development of robust, normal stress responses in disadvantaged or pre-term infants.

The 'cuddle hormone' oxytocin is known to be involved in establishing strong parent-infant bonds. Until very recently, most studies of oxytocin levels have been in parents – most often mothers – or older children. Recent genetic studies, however, have suggested that infant oxytocin levels are likely to play an important role in emotional development and that this should be tested further. Jones and Sloan described research in their own group that suggests a relationship between breastfeeding and kangaroo care, rising infant oxytocin levels, and bonding in infants of depressed mothers. They propose that oxytocin can act as a 'buffer' to mitigate the risk that chronic stress poses to the development of infant temperament.

Jones and Sloan then discuss the role that parental cortisol and oxytocin release plays in the developing temperament. The mother's role is of course the more important, particularly before birth where it is impossible to completely separate the maternal hormone system from the foetal one. Hormones pass through the placenta, which may either act as a shield against stress or a means of exposure to it. When a pregnant woman is stressed, her cortisol is transmitted through the placenta to the foetus, where very high levels may even disrupt brain development; other hormones released during stress also affect foetal development. Abnormally high levels of these hormones early in pregnancy have been associated with premature birth, with low birth weight, with a more 'difficult' infant temperament at three months, and even with difficulties with social and cognitive development in childhood. Cortisol can be transmitted physically from a mother to her infant after birth, in breast milk, but the main effect of maternal – and paternal – stress hormones on infant development is increasingly through parental behaviour.

Maternal oxytocin levels are strongly associated with the development of the bond between mother and baby, with elevated levels being associated with more sensitive care. Infants respond to sensitive care by touching their mothers more, and this developing bond helps infants regulate their emotions. Conversely, a 'vicious cycle' can occur with maternal depression linked to poor bonding, low or dysregulated oxytocin levels and emotional and behavioural problems in infants and children. Recent studies have also shown a definite although less pronounced link between paternal oxytocin levels, the development of regulation in infants and family bonding.

In summarising their review, Jones and Sloan pose some important questions to be addressed by future research. Our knowledge of how these hormones and others interact during early development remains incomplete, and new experimental methodologies continue to be developed. They suggest that it would be useful to try to integrate the various theories of temperament development together, and recent research in adults into the influence of genetic and gene expression variations on behaviour could usefully be applied to infants. Understanding temperament development enough to be able to influence it will require an even more multi-disciplinary approach.

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