Family Perspectives

Volume 5 | Issue 1 Article 6

2023

Oxytocin and Attachment Development

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Abstract

Secure attachment is optimal for human socioemotional development, and oxytocin may impact the development and outcome of attachment by promoting maternal care, reducing amygdala activity, and increasing prosocial behavior. The formation of attachment is influenced by maternal feeling and behavior during early pregnancy and through the postpartum period, as is seen in research showing that oxytocin influences maternal-fetal bonding, initiates mother-child bonding immediately following birth, and increases attentive maternal behavior throughout the infant's life (Bethlehem et al., 2013). Because oxytocin is an anti-stress hormone with anxiolytic and stress protective properties, it modulates amygdala activity, enhances the processing of positive social stimuli, reduces behavioral stress responses, dampens sympathetic nervous system activity, and decreases cortisol levels (Buchheim et al., 2009). Research indicates that oxytocin works with the amygdala to influence social approach behaviors like increased empathy, feelings of trust, reduced reactions to social stress and anxiety, the facilitation of social interaction, improved social memory, better social and emotional regulation, higher-quality parental care and bonding, better couple interaction and pair bonding (Alves, et al., 2015).

Attachment, like many developmental processes, includes influences of both environmental and biological factors (Moore, 2003). Research on the development of attachment suggests that prenatal and postnatal experiences, especially those with a caregiver, influences the infant's temperament and impact the infant's attachment circuitry within the brain (Abraham et al., 2021; Szymanska et al., 2017). Therefore, early attachment is thought to have the power to influence behavioral traits in later life (Szymanska et al., 2017).

Research suggests that attachment is a normative universal process resulting from an innate bias to signal needs, meaning that every neuro-typical infant has the capacity to form some sort of attachment, regardless of the quality of care received (Szymanska et al., 2017; Van Ijzendoorn & Sagi-Schwartz, 2008). Secure attachment is formed through repeated interactions with the caregiver in an ideally caring and stimulating environment where the caregiver offers warmth and responsiveness while appropriately meeting the infant's needs (Szymanska et al., 2017; Van Ijzendoorn

& Sagi-Schwartz, 2008). Specifically, caregivers of securely attached infants tend to use appropriate gaze duration, practice checking behaviors, react to the child's cues, and engage with the infant, which allows the infant to learn that they can rely on the caregiver (Szymanska et al., 2017). Caregivers of insecurely attached infants, on the other hand, tend to not be as aware of their child's specific signaling behaviors and, as a result, they respond to those signals more infrequently and/or more inappropriately. Both secure and insecure attachment styles are aimed at maintaining close proximity to the caregiver in order to acquire needed resources and protection. Secure attachment specifically is optimal for social, emotional, and cognitive development and programming of the brain (Abraham et al., 2021; Riem et al., 2016; Strathearn et al., 2009), while insecure attachment can have extremely negative effects in many aspects of development (Szymanska et al., 2017).

Recently, researchers have started to study the process of how attachment forms and what aspects of this process alter neural development to impact later behavior. Some research suggests that the emotional processing center of the brain, the limbic system, which is comprised of structures such as the hippocampus and the amygdala, may be impacted by prenatal and postnatal experiences, especially those with a caregiver, and may influence later behavioral outcomes (Grimm et al., 2014). It would appear that the early caregiving environment interacts with the infant's temperament and impacts the limbic system. The limbic system, particularly the amygdala, develops to inform later behavioral responses, but the mechanisms of how this occurs are not widely understood.

In an attempt to find a common factor that connects caregiving, the amygdala, and later social behavior with attachment, recent research has presented evidence that indicates that oxytocin—a hormone that is produced by the hypothalamus and distributed through the bloodstream by the pituitary gland—may play a major role in forming attachments with others, developing the structure and function of the amygdala, and influencing the brain in later social affiliations (Alves et al., 2015). Although there are many components that have powerful impacts on attachment development, the purpose of this paper is to suggest that oxytocin influences the development and outcomes of attachment by promoting maternal care, reducing infant/child amygdala activity, and motivating prosocial behavior in childhood.

Maternal Care

Oxytocin may impact the formation of attachment by influencing maternal feeling and behavior during early pregnancy and through the postpartum period (Bethlehem et al., 2013; Riem et al., 2017; Szymanska et al., 2017). Research on maternal bonding and oxytocin levels suggest that oxytocin increases from early to late

pregnancy and is correlated with higher maternal-fetal bonding: a feeling of closeness, protectiveness, and responsibility to meet the infant's needs (Szymanska et al., 2017). Research also shows that immediately following labor and delivery, oxytocin is released and acts on the brain to stimulate maternal behavior, which plays a central role in initiating mother-child bonding by decreasing maternal stress and enhancing calmness and feelings of connection (Szymanska et al., 2017). Oxytocin also influences other maternal functions, including contractions during childbirth and the let-down reflex during lactation (Alves et al., 2015). Mothers with higher levels of oxytocin in the postpartum period demonstrate more attentive maternal behaviors that foster the development of attachment, like eye gaze, 'motherese' vocalizations (i.e., simplified and repetitive speech with exaggerated intonation), positive affect, and affectionate touch (Eapen et al., 2014; Riem et al., 2016; Szymanska et al., 2017). Levels of oxytocin during pregnancy may even be predictive of postpartum depression, which decreases maternal bonding and interferes with maternal synchronization with the infant's state (Eapen et al., 2014; Szymanska et al., 2017). In sum, oxytocin provides the foundation for parental-infant bonding (Abraham et al., 2021), as indicated by research, oxytocin levels during pregnancy and the postpartum period are related to maternal attachment representation, responsive and warm maternal behavior with the child, and repeated checking behavior. This suggests a link between oxytocin production and the acceptance of one's own child and the desire to influence their development (Szymanska et al., 2017), all of which reflect the type of sensitive caregiving associated with secure attachments.

In addition to motivating maternal behavior, oxytocin also rewards such behavior, which leads to even greater caregiver involvement (Isgett et al., 2017; Kohlhoff et al., 2021). Research suggests that oxytocin links social cues, such as an infant's facial expression (e.g., smiles), with the reward system (i.e., dopamine-associated reinforcement pathways) in the mother's brain, creating a positive feedback loop that encourages the detection of a child's signal and responsive caregiving behavior (Mielke et al., 2018; Strathearn et al., 2009; Szymanska et al., 2017). In other words, when interacting with their infants, mothers with secure attachment patterns may produce more oxytocin, which increases the experience of reward and further contributes to the mother's ability to provide consistent and nurturing care by exciting neurons in reward centers of the brain (Kohlhoff et al., 2021; Strathearn et al., 2009). Some studies even indicate that oxytocin increases emotional regulation and decreases amygdala activation in response to the child's cues, which means that oxytocin reduces negative emotional arousal in response to a child's demands, promoting the necessary maternal responsiveness and proximity to the child (Bethlehem et al., 2013; Riem et al., 2016; Szymanska et al., 2017). Each of these oxytocin-rewarded maternal behaviors

help the infant to create a healthy attachment style that will influence their relationships throughout their life (Bethlehem et al., 2013; Riem et al., 2016; Szymanska et al., 2017).

Evidence from research also indicates that oxytocin is not only influential in motivating and rewarding maternal behavior (Riem et al., 2016), but the effect of oxytocin on the parent also affects oxytocin processes in the infant (Alves et al., 2015). In other words—the oxytocin system, the system that sustains affiliation and helps control the stress, immune, and reward systems—drives a biobehavioral feedback loop in which parental oxytocin supports parental caregiving, and this synchronous caregiving, in turn, shapes the infant's oxytocin system (Abraham et al., 2021; Feldman et al., 2013). Biobehavioral synchrony—the process by which parent and child physiology and behaviors are coordinated during social contact (Abraham et al., 2021; Feldman, 2013), suggests that oxytocin functioning in a child is associated with patterns of parental care (Abraham et al., 2021; Feldman et al., 2013). The synchrony of oxytocin production between parent and child is important because the child's oxytocin system influences how he/she responds to and seeks parental care which is one indicator of the security they experience in the context of their attachment with their caregiver (Riem et al., 2017; Szymanska et al., 2017).

Through repeated interactions with a warm and responsive caregiver, a child is then able to develop a stable cognitive-emotional schema of the caregiver's availability for reducing stress and providing comfort and protection in potentially threatening situations (Buchheim et al., 2009). Specifically, studies show that through repeated moments of parent-child synchrony in gaze, affect, vocalization, and touch, parents help organize the child's stress management system and cortisol activity (Abraham et al., 2021). As a result, parental synchrony in early childhood may be predictive of regulatory outcomes later in life (Abraham et al., 2021). Furthermore, neonates with higher oxytocin levels are more likely to show prosocial behavior and parent-child synchrony and, therefore, may obtain more parent comforting and sensitivity, which drives the development of a secure attachment (Szymanska et al., 2017).

It is important to note, however, that differences in the maternal brain and oxytocin responses to infant cues, may be associated with adult attachment patterns (Strathearn et al., 2009). Securely attached mothers tend to have more activation in reward areas of the brain and show more warmth and responsiveness, but mothers with insecure attachment patterns, which usually result from early life maltreatment, are less sensitive

and less likely to establish a secure relationship with their child (Kohlhoff et al., 2021; Mielke et al., 2018; Spieker et al., 2018; Strathearn et al., 2009). Research indicates that the differences in the maternal behavior and sensitivity of secure and insecure mothers is due to differences in the oxytonergic system (Mielke et al., 2018). Differences found in insecurely attached mothers include less oxytocin production and lower sensitivity to oxytocin in the brain (Mielke et al., 2018). However, research indicates that oxytocin administration may increase parent-child prosocial interaction through bonding, sensitivity, synchrony, and protective responses (Riem et al., 2016; Szymanska et al., 2017). Understanding the influences of the mother's attachment style on her behavior is important because the children of insecure mothers may tend to have greater difficulties regulating affect, forming peer bonds, and establishing securely attached relationships in later life (Strathearn et al., 2009). The evidence presented in this section strongly suggests that oxytocin encourages positive maternal behavior which subsequently affects attachment by initiating the formation of a healthy mother-child bond, thus laying the foundation for a positive internal working model of attachment and a well-regulated oxytocin system that programs the child to see people and relationships as good and rewarding. In this way oxytocin heavily influences how individuals interact with, attach to, and build relationships with others as they grow.

The Amygdala

The amygdala, which is influenced by oxytocin, is a key brain region for fear, anxiety, and emotional regulation and plays a crucial role in both emotional and social behavior (Bethlehem et al., 2013; Riem et al., 2016; Sobota et al., 2015). Research suggests that the medial amygdala is critical for the expression of many social behaviors and has many roles, including processing pheromonal signals, differentiating social sensory cues, decreasing aggression and fear, recognizing emotion in others, enhancing social recognition memory, engaging in social learning, and motivating social affiliation and maternal bonding (Ramm & Hong, 2021). In addition, the medial amygdala responds to complex features of the social environment, like facial expression, facial identity, pair bonding, and jealousy (Raam & Hong, 2021). Furthermore, research shows that the centromedial amygdala is active during experiences involving empathy and social reward (Raam & Hong, 2021).

Neurobiological research on oxytocin shows that it is significantly involved in the socio-emotional cognition process and modulates underlying amygdala-driven networks (Eckstein et al., 2019). Because the amygdala has a high density of oxytocin receptors, oxytocin exposure influences the formation of synapses in the

amygdala and influences prosocial behavior by reducing activity in the amygdala, which also decreases the activation of downstream anxiety centers (Sobota et al., 2015). In particular, oxytocin enhances the processing of positive social stimuli, reduces behavioral stress responses, dampens sympathetic nervous system activity, decreases cortisol, and modulates amygdala activity by inhibiting its processing of fear and threat stimuli and softening the amygdala's response to social stimuli (Buchheim et al., 2009; Gamer & Buchel, 2012; Grimm et al., 2014). In this way, oxytocin does not directly affect social cognition and social behavior but rather influences functioning of the amygdala in ways that increase healthy social behavior and promote the development of secure attachments (Auyeung et al., 2013; Nishina et al., 2018). All in all, oxytocin acts as an anti-stress hormone and is thought to have anxiolytic and stress protective properties that allow individuals to relax into a calm state of social affiliation (Abraham et al., 2021; Riem et al., 2016; Sobota et al., 2015).

As stated earlier, research indicates that oxytocin has the ability to calm the mother's amygdala during and after childbirth and also during stressful situations that occur during parenting (Riem et al., 2016). Looking at this phenomenon, a study conducted by Riem et al. (2016) found that oxytocin promotes sensitive responses to crying infants by increasing the secure mother's empathetic reaction to the infant and reducing her anxious feelings. This allows her to warmly meet the child's needs. This study also found that amygdala hyperactivity and lower oxytocin levels may help explain why insecure mothers tend to be more irritable, more aversive, and more angry during stressful parenting events (Riem et al., 2016). Riem et al. (2016) found that negative emotions, like irritation, aversion, and anger, undermine sensitive child-oriented parental responses, such as soothing the child, and increase the risk of using harsh caregiving responses that can have very damaging effects on attachment formation and behavioral outcomes (Riem et al., 2016). Interestingly, the study also found that oxytocin administered to individuals with insecure attachment representation decreased the use of harsh responses and amygdala reactivity in response to crying (Riem et al., 2016). This suggests that even when administered intranasally oxytocin reduces negative parental responses to infant distress by dampening the effects of the amygdala (Riem et al., 2016).

Interaction between proximal and individual processes have a mutual influence on development (Abraham et al., 2021). Understanding the influence of maternal care in correlation to the child's temperament and behavior is important because research shows that sensitive and responsive parenting mitigates the child's cortisol response to social stressors (Abraham et al., 2021). Meanwhile parental insensitivity and intrusiveness negatively alters the development of the child's neurobiological stress response and threat-detection

circuits and correlates with higher cortisol production (Abraham et al., 2021). This means unresponsive parenting may lead to lower levels of oxytocin in the child and a structurally and functionally altered amygdala in the developing child, which is correlated with an insecure attachment style (Grimm et al., 2014).

Studies about institutional neglect and/or disturbed infant attachment show that children who are unable to form an attachment due to the absence of a direct caregiver have abnormal structural development and functioning in the amygdala and other regions of the brain associated with cognition and emotional regulation (Bick & Nelson, 2016; Lyons-Ruth, 2016). In particular, research reports altered gray matter volumes in brain regions associated with central oxytocin systems (e.g., amygdala, hypothalamus, and nucleus accumbens) in people who have experienced early life maltreatment and neglect, suggesting that there may be an association between oxytocin and brain morphometry (Mielke et al., 2018). In a study conducted by Lyons-Ruth et al. (2016), they found that attachment disturbances in infancy, which are usually correlated with impairments in the parental regulation provided to the infant, may be predictive of larger left amygdala volume in adults and a correlated increase in adult dissociation and limbic irritability, indicating that disturbed infant attachment affects adult amygdala volume and psychopathology.

It is important to understand the long-term effects of structural and functional alterations in brain regions like the amygdala because they influence the individual in such a way that impacts their offspring. For example, a mother with low levels of oxytocin and a hyperactive amygdala is less likely to be warm and sensitive to her child (Mielke et al., 2018), which may lead to insecure attachment and poor development of the amygdala in that child, causing behavioral problems in later life and creating a negative cycle. To demonstrate this, Mielke et al. (2018) did a study that found that women without early life maltreatment show a positive association between gray matter volume in both the nucleus accumbens, the neural interface between motivation and action, and the hypothalamus, the control center for the hormonal system, and oxytocin. The authors conclude that women without early life maltreatment and who have a secure attachment style are more likely to have functional reward processing, which may increase maternal behavior (Mielke et al., 2018). On the other hand, women with early life maltreatment tend to have a negative association between gray matter volume in the amygdala and oxytocin, suggesting that in addition to having disrupted reward processing, insecurely attached women are more likely to have higher levels of anxiety and decreased socialization due to higher rates of amygdala activation (Mielke, et

al., 2018). All of this suggests that oxytocin modulates amygdala activation by reducing anxiety and motivating affiliation, leading to optimal development and prosocial behavior (Bethlehem et al., 2013) and better parenting and developmental outcomes for one's offspring, including a secure attachment style. The research presented in this section indicates that oxytocin influences the activity and structure of the amygdala which consequently affects attachment by altering the way that the individual processes and responds to interactions with other people.

Social Behavior

The ability to form attachments is a fundamental and essential aspect of forming social relationships (Buchheim et al., 2009) and, therefore, has long-term impacts on social and emotional functioning and development (Kohlhoff et al., 2021). According to attachment theory, repeated interactions with a caregiver allow children to form an internal working model of relationships that shapes how they interpret and respond emotionally to socially interactive situations (Feldman et al., 2013). This suggests that the human capacity to form affiliative bonds with social partners outside of the family is influenced by biobehavioral experiences beginning with the mother-infant bond (Feldman et al., 2013). It is of value to understand that biobehavioral experiences within the parent-infant bond shape children's affiliative biology and social behavior across multiple attachments because research repeatedly shows that having a secure attachment and close friends is associated with mental health, physical well-being, and life satisfaction (Feldman et al., 2013).

The neuropeptide oxytocin may help modulate social behavior throughout life (Bethlehem et al., 2013; Gamer & Buchel, 2012) by influencing various brain regions and behaviors that are associated with the ability to form normal social attachments and affiliation (Alves et al., 2015; Buchheim, et al., 2009; Eckstein et al., 2019). Research indicates that oxytocin works directly and indirectly with the amygdala and other brain regions to influence social approach behaviors and social functions (Alves et al., 2015; Bethlehem et al., 2013; Eckstein et al., 2019; Sobota et al., 2015). These functions include increased empathy, feelings of trust, reduced reactions to social stress and anxiety, the facilitation of social interaction, greater social interaction time, improved social memory, better social and emotional regulation, higher-quality parental care and bonding, more couple interaction and pair bonding, and more (Alves et al., 2015; Bethlehem et al., 2013; Eckstein et al., 2019; Sobota et al., 2015).

Because children with altered oxytocin sensitivities and hyperactive amygdalas do not experience many of the benefits mentioned above, they tend to struggle to engage with others socially and often show patterns of behavioral inhibition. In particular, the children of insecure mothers, who typically have an insecure attach-

ment style themselves, may tend to have greater difficulties regulating affect, forming peer relationships, and establishing securely attached relationships in later life (Strathearn et al., 2009). Many of these children may be behaviorally inhibited and experience poorer respiratory sinus arrhythmia (RSA), meaning that they have less cognitive control over their emotional responses (Isgett et al., 2017).

As mentioned earlier, disturbed infant attachment affects adult amygdala volume and psychopathology (Lyons-Ruth, 2016). Some additional mental and behavioral disorders that may be correlated with amygdala structural abnormalities include exaggerated fear responses, social inhibition, externalizing and internalizing problems, difficulties with emotional and behavioral regulation, abnormal direction of eye gaze in social contexts, and inhibited social behavior like threat detection, emotion reading, and processing novel stimuli (Bick & Nelson, 2016; Lyons-Ruth et al., 2016; Sobota et al., 2015). Research indicates that such impairments could also be related to poor patterns of functional connectivity between the medial prefrontal cortex—the brain area that plays a regulatory role in many cognitive functions, including attention, inhibitory control, habit formation, and memory—and the amygdala (Bick & Nelson, 2016; Grimm et al., 2014). This means that the prefrontal cortex cannot override the reaction of the amygdala when it would be appropriate to do so, as it would in a normal brain (Bick & Nelson, 2016; Grimm et al., 2014). A lack of connectivity may be due to the structural and functional changes in the amygdala and the reduction of oxytocin's suppressing effect on cortisol levels as a result of early life stress (Grimm et al., 2014; Lyons-Ruth et al., 2016). While early life stress may initially inhibit the formation of a healthy attachment with a caregiver because of a lack of oxytocin, a hyperactive oxytocin-deprived amygdala with a poor connection to the prefrontal cortex drives the individual's reaction to social interactions, resulting in a consistent pattern of forming insecure attachments throughout their life (Bick & Nelson, 2016; Lyons-Ruth et al., 2016).

The oxytocin system is important in forming social relationships because it motivates humans to bond with others, gives saliency to social cues, and reduces the stress involved in social initiation (Feldman et al., 2013). Beginning around the age of three, children start to form friendships with same-aged peers, and research suggests that doing so requires children to draw on mechanisms of social learning from parents and on the functioning of their own oxytocin system (Feldman et al., 2013). Their emotional and behavioral state is now less regulated by their caregiver and is increasingly regulated by their own socioemotional system. Research shows that a child's social reciprocity with friends at three years of age is associated with the mother's oxytocin-related genes and hormones, mother-child reciprocity, and the parent-child attach-

ment, which allows the child to continue to learn how to interact socially (Feldman et al., 2013). Interestingly, Feldman et al. (2013) also found that a child's social reciprocity with friends is likewise associated with the child's own oxytocin levels, social competence, self-regulation, and level of aggression. However, oxytocin does not just affect young individuals as they learn how to engage with the social world.

Oxytocin can have direct effects on the social behavior of adults. Studies that administer oxytocin to adult humans show that oxytocin may promote social approach behavior by momentarily reducing endocrine and psychological responses to social stress, regulating mood, stimulating trust, empathy, understanding, and in-group altruism (Auyeung et al., 2013; Bethlehem et al., 2013; Buchheim et al., 2009; Riem et al., 2016). This enhances their ability to infer the mental states of others and recognize emotion, improves social memory, motivates affiliation and pair bonding, and encourages other social-cognitive abilities, such as social gaze and eye gaze (Auyeung et al., 2013; Bethlehem et al., 2013; Buchheim et al., 2009; Riem et al., 2016). Oxytocin is also thought to influence adults during periods of romantic bond formation when plasma oxytocin levels increase, deepening the sense of connection (Feldman et al., 2013). Thus, in both parental and romantic attachment higher peripheral oxytocin correlates with greater social reciprocity between partners (Feldman et al., 2013).

Attachment is transferred cross-generationally such that adults who report better parental care in childhood show higher peripheral oxytocin, more sensitive parenting, and greater activation in oxytocin rich brain areas, which in turn allows their offspring to form optimal oxytocin systems and secure attachment (Feldman et al., 2013; Kohlhoff et al., 2021; Strathearn et al., 2009). A well-functioning oxytocin system may be critical for optimal social and emotional development and ability throughout human life and, therefore, is crucial to the development of attachment.

Conclusion

In conclusion, secure attachment is optimal for human socioemotional development, and, while there are many factors that impact attachment, oxytocin may have a more powerful influence on the development and outcomes of attachment than has previously been thought. Specifically, recent research on oxytocin and the development of attachment suggests that oxytocin impacts the development and outcome of attachment by promoting maternal care to form a secure attachment between parent and child (Bethlehem et al., 2013; Eapen et al., 2014; Riem et al., 2017; Szymanska et al., 2017). This helps to develop the structure and function of the brain in a way that reduces hyperactivity in the amygdala (Mielke et al., 2018; Ramm & Hong, 2021;

Riem et al., 2016; Sobota et al., 2015) and influences the brain to increase prosocial behavior later in life (Bick & Nelson, 2016; Feldman et al., 2013; Kohlhoff et al., 2021; Lyons-Ruth et al., 2016).

It is of value to note that oxytocin's role in the development of a secure mother-child attachment and the impact of this bond is already empirically established, but there is more to learn about how oxytocin can be used to affect attachment development. Research shows that a secure attachment between caregiver and infant does in fact influence the functionality of the child's amygdala (Riem et al., 2016), and the amygdala influences social behavior throughout the individual's life (Mielke et al., 2018). In addition to helping in the formation of a secure attachment in early life by promoting maternal care (Bethlehem et al., 2013; Riem et al., 2017; Szymanska et al., 2017), sensitivity to oxytocin also leads to a greater capacity for attachment throughout life by inhibiting the reaction of the amygdala (Mielke, et al., 2018; Riem et al., 2016). Oxytocin drives human connection and improves social behavior even into adulthood (Feldman et al., 2013; Lyons-Ruth et al., 2016), allowing for continual attachment formation. Therefore, in the future, more research should be done to determine how oxytocin can be used as an intervention to improve mother-child bonds (e.g., mothers with postpartum depression, insecure attachment, or early life maltreatment), decrease hyper-reactivity of the amygdala in social settings (e.g., socially withdrawn or socially aggressive individuals), and to improve the social behavior and feelings of attachment in adults (e.g., insecurely attached individuals or those with other deficits in social behavior). Research on the administration of oxytocin is important because social behavior and affiliation is essential for the well-being of all people. Acquiring more knowledge in this area has the potential to improve the oxytocin systems of coming generations, fostering the formation of healthy attachments.

References

Abraham, E., Zagoory-Sharon, O., & Feldman, R. (2021). Early maternal and paternal caregiving moderates the link between preschoolers' reactivity and regulation and maturation of the HPA-immune axis. *Developmental Psychobiology, 63*(5). 1482-1498. https://doi.org/10.1002/dev.22089

Alves, E., Fielder, A., Ghabriel, N., Sawyer, M., & Buisman-Pijlman, R. T. A. (2015). Early social environment affects the endogenous oxytocin system: *A review and future directions. Frontiers in Endocrinology, 6*, 32. https://doi.org/10.3389/fendo.2015.00032

Auyeung, B., Lombardo, M. V., & Baron-Cohen, S. (2013). Prenatal and postnatal hormone effects on the human brain and cognition. *Pflugers Archiv-European Journal of Physiology, 465*(5), 557-571. https://doi.org/10.1007/s00424-013-1268-2

Bethlehem, R. A., van Honk, J., Auyeung, B., & Baron-Cohen, S. (2013). Oxytocin, brain physiology, and functional connectivity: A review of intranasal oxytocin fMRI studies. *Psychoneuroendocrinology, 38*(7), 962-974. https://doi.org/10.1016/j.psyneuen.2012.10.011

Bick, J., & Nelson, C. A. (2017). Early experience and brain development. *Wiley Interdisciplinary Reviews: Cognitive Science, 8*(1-2), e1387. https://doi.org/10.1002/wcs.1387

Buchheim, A., Heinrichs, M., George, C., Pokorny, D., Koops, E., Henningsen, P., O'Connor, & M., Gundel, H. (2009). Oxytocin enhances the experience of attachment security. *Psychoneuroendocrinology, 34*(9), 1417-1422. https://doi.org/10.1016/j.psyneuen.2009.04.002

Eapen, V., Dadds, M., Barnett, B., Kohlhoff, J., Khan, F., Radom, N., & Silove, D. M. (2014). Separation anxiety, attachment, and inter-personal representations: Disentangling the role of oxytocin in the perinatal period. *PLoS One: Social Psychiatry, 9*(9), e107745. https://doi.org/10.1371/journal.pone.0107745

Eckstein, M., Bamert, V., Stephens, S., Wallen, K., Young, L. J., Ehlert, U., & Ditzen, B. (2019). Oxytocin increases eye-gaze towards novel social and non-social stimuli. *Social Neuroscience, 14*(5), 594-607. https://doi.org/10.1080/17470919.2018.1542341

Feldman, R., Gordon, I., Influs, M., Gutbir, T., & Ebstein, R. P. (2013). Parental oxytocin and early caregiving jointly shape children's oxytocin response and social reciprocity. *Neuropsychopharmacology, 38*(7), 1154-1162. https://doi.org/10.1038/npp.2013.22

Gamer, M., & Buchel, C. (2012). Oxytocin specifically enhances valence-dependent parasympathetic responses. *Psychoneuroendocrinology, 37*(1), 87-93. https://doi.org/10.1016/j.psyneuen.2011.05.007

Grimm, S., Pestke, K., Feeser, M., Aust, S., Weigand, A., Wang, J., … & Bajbouj, M. (2014). Early life stress modulates oxytocin effects on limbic system during acute psychosocial stress. *Social Cognitive and Affective Neuroscience, 9*(11), 1828-1835. https://doi.org/10.1093/scan/nsu020

Isgett, S. F., Baczkowski, B. M., Grewen, K. M., Kok, B. E., Algoe, S. B., & Fredrickson, B. L. (2017(8), 1156-1165. http://doi.org/10.1037/emo0000301

Kohlhoff, J., Karlov, L., Dadds, M., Barnett, B., Silove, D., & Eapen, V. (2021). The contributions of maternal oxytocin and maternal sensitivity to infant attachment security. Attachment and Human Development, 1-16. https://doi.org/10.1080/14616734.2021.2018472

Lyons-Ruth, K., Pechtel, P., Yoon, S. A., Anderson, C. M., & Teicher, M. H. (2016). Disorganized attachment in infancy predicts greater amygdala volume in adulthood. Behavioural Brain Research, 308, 83-93. https://doi.org/10.1016/j.bbr.2016.03.050

Mielke, E. L., Neukel, C., Bertsch, K., Reck, C., Mohler, E., & Herpertz, S. C. (2018). Alterations of brain volumes in women with early life maltreatment and their association with oxytocin. Hormones and Behavior, 97, 128-136. https://doi.org/10.1016/j.yhbeh.2017.11.005

Moore, D. S. (2003). The dependent gene. New York: Henry Holt.

Nishina, K., Takgishi, H., Fermin, A. S. R., Inoue-Murayama, M., Takahashi, H., Sakagami, M., & Yamigishi, T. (2018). *Association of oxytocin receptor gene with attitudinal trust: Role of amygdala volume. Social Cognition and Affective Neuroscience, 13*(10), 1091-1097. https://doi.org/10.1093/scan/nsy075

Raam, T., & Hong, W. (2021). Organization of neural circuits underlying social behavior: A consideration of the medial amygdala. Current Opinion in Neurobiology, 68, 124-136. https://doi.org/10.1016/j.conb.2021.02.008

Riem, M., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2016). Intranasal administration of oxytocin modulates behavioral and amygdala responses to infants crying in females with insecure attachment representations. *Attachment and Human Development, 18*(3), 213-234. https://doi.org/10.1080/14616734.2016.1149872

Sobota, R., Mihara, T., Forrest, A., Featherstone, R. E., & Siegel, S. J. (2015). Oxytocin reduces amygdala activity, increases social interactions, and reduces anxiety-like behavior irrespective of NMDAR antagonism. Behavioral Neuroscience, 129(4), 389-398. https://doi.org/10.1037/bne0000074

Strathearn, L., Fonagy, P., Amico, J., & Montague, P. R. (2009). Adult attachment predicts maternal brain and oxytocin response to infant cues. Neuropsychopharmacology, 34, 2655-2666. https://doi.org/10.1038/npp.2009.103

Szymanska, M., Schneider, M., Chateau, S. C., Nezelof, S., & Vulliez, C. L. (2017). Psychophysiological effects of oxytocin on parent-child interactions: A literature review on oxytocin and parent-child interactions. *Psychiatry and Clinical Neuroscience, 71*(10), 690-705. https://doi.org/10.1111/pnc.12544

Van Ijzendoorn, M. H., & Sagi-Schwartz, A. (2008). Cross-cultural patterns of attachment: Universal and contextual dimensions. In Cassidy, J., & Shaver, P.R. (Eds.) Handbook of attachment. (pp. 880-905). The Guilford Press.