The Transition to Motherhood: Psychoanalysis and Neuroscience Perspectives

Mariana Von Mohr[1], Linda C Mayes[2], Helena JV Rutherford[2]

[1]University College London, [2]Yale Child Study Center

Abstract

Motherhood is a unique transitional period in adulthood accompanied by distinct changes in the mind and brain. Although psychoanalytic and neuroscientific theory employ different levels of abstraction and methodology, there may be value in considering the synergy between the two fields for understanding this critical transitional period for women. Here we review this literature and present a joint model of the neurobiological and psychic re-organization that may occur to support motherhood. Our approach highlights the value of considering multiple perspectives theoretically, as well as clinically, given the insight of neuroscience and psychoanalysis to the development and refinement of parenting interventions.

Although psychoanalytic theory has provided substantial insight into the impact of the primary object on an individual's inner world throughout development, the psychic development in adulthood of the primary object herself has received less attention. Becoming a mother may constitute an important transitional period (Erikson, 1959; Rappaport, 1994), where psychic changes occur to enable a mother to identify with her infant and sensitively respond to her infant's needs (Winnicott, 1956 [1975]). Further, how a mother adapts to these changes and responds to her child may have additional consequences for her infant's socio-emotional development (Pines, 1972; Rutherford & Mayes, 2011; Winnicott, 1956 [1975]). Critically, in addition to the psychic re-organization accompanying motherhood, research also suggests an accompanying neurobiological re-organization (Kinsley & Lambert, 2008; Rutherford, Potenza & Mayes, 2013). Broadly, this re-organization includes an adaptation of the brain's reward system, as well as changes in those brain circuits recruited in processing emotional valence and underlying executive functions (Gonzales, Atkinson & Fleming, 2009; Rutherford & Mayes, 2011; Swain, 2008; 2011).

Although psychoanalysis and neuroscience reflect typically disparate literatures and differing domains of discourse with discussion at the level of the mind versus the brain, there may be significant value in considering the convergence, as well as divergence, of psychoanalytic and neuroscientific theories regarding a woman's transition to motherhood. This transition may be normative in understanding how women more generally transition into the maternal role, and also clinical, by focusing on how mothers may struggle in their caregiving role with an accompanying compromise in the mother-infant relationship. Therefore, in this paper we will first review psychoanalytic perspectives on the transition to motherhood and then the neurobiological re-organization that has been described during pregnancy and postpartum.

Second, we consider how these perspectives incorporate past experience with a child in the transition to motherhood and the potential effects of maternal past experience on how she responds to her child. Third, we consider the critical role of individual differences, including clinical symptomatology, in the psychic and neural re-organization associated with motherhood. We conclude with a consideration of the value of integrating psychoanalytic and neuroscience theories in guiding our understanding of period of transition, including where further development of these theoretical perspectives is needed.

The Transition to Motherhood

From an evolutionary perspective, psychic and neurobiological changes accompanying motherhood may occur to ensure the survival of highly dependent infants (Lorenz, 1943). These changes may include heightening mothers' sensitivity toward their child through enhancing the mother's ability to perceive and respond appropriately to their infant's needs, as well as through increasing levels of motivation for caretaking behavior (Rutherford & Mayes, 2011; Swain, 2011). Psychoanalytically, this heightened sensitivity may be achieved through mothers' increasing identification with her child (Pines, 1972; Winnicott, 1956 [1975]) and biologically through substantial shifts in the hormones progesterone and estrogen triggering maternal behavior (Bridges, 1984). Given that these postulations reflect different levels of understanding, we will first review the psychic and then the neurobiological re-organization that may underscore the transition to motherhood.

Psychic re-organization. Pregnancy and the onset of motherhood have been recently considered as critical periods of transition in the lifecycle of women (Erikson, 1959; Rappaport, 1994), where an intra-psychic re-organization occurs (Benedek, 1959; Bibring, 1961; Pines, 1972, 1982). Critically, the transition to motherhood –particularly the first pregnancy– may also

constitute a time of crisis, where women must search for a female identity and this marks the final stages of their being independent single units (Bibring, 1959; Pines, 1972).

This shift from an independent single unit to the irreversible mother-infant dyadic relationship is an ongoing and emotionally complex process (Pines, 1972). Beginning in pregnancy, women must progressively re-elaborate their internal representation of the relationship with their own mother – allowing at the same time the process of identification with the fetus (Pines, 1972). Naturally, depending on the quality of internalized object relations, women will experience the unborn child in different ways at different periods of their pregnancy (Pines, 1972, 1978). As a result, changes in internalized objects and identifications may lead to a change in a mother's psychic structure. For new mothers in particular, psychic changes and ambivalence may characterize this process as it involves new identifications, regressions and the resolution of early conflicts with her own mother (Bibring, 1959; Pines, 1978). Here a mother reappraises the task of separation individuation by experiencing herself as the child of her own mother and then as a mother distinct from her own parent (Pines, 1978, 1982). In other words, she identifies with her own mother, her fetus, and herself as an infant.

Throughout this separation individuation process, psychic re-organization in the transition to motherhood also requires an adaptation of internal boundaries between self and other (Lester & Notmann, 1988). Indeed, by the last months of pregnancy and continuing throughout the postpartum period, the mother both views the fetus as a separate entity and also as part of the mother herself (Ammaniti and Trenitini, 2009; Fonagy & Target, 1996). This adaptation promotes cathexis (i.e., investment of libidinal energy) of the infant as a separate object and an extension of the mother's body, a cathexis that is translated to the baby once it is born (Pines, 1972). Progressive cathexis of the infant across pregnancy and the postpartum is

vital, as it may enable mothers to bond and identify with their infant and therefore, to accurately attend to their needs (Benedek, 1959; Bibring, 1959; Pines, 1972; Walter & McCloyd, 2009). Taken together, ongoing processes including new identifications and infant-cathexis underlie the psychic re-organization in the transition to motherhood.

In addition to this infant-cathexis process, a particular maternal mental state may accompany the transition to motherhood in order to accurately meet the physical and psychological needs of their infants (Ammaniti & Trentini, 2009; Winnicott, (1956[1975]). Notably, Winnicott (1956 [1975]; 1960 [1965]) used the term 'primary maternal preoccupation' to describe a time-limited psychic state of heightened sensitivity in mothers. An organized state, comparable to a withdrawn or dissociated state, is promoted in this "normal illness" (i.e., mothers must be healthy enough to achieve a state of heightened sensitivity; Winnicott, 1956 [1975], pp. 302), which temporarily takes over and enables a mother to adapt to her infant's needs by being more attuned (Winnicott, 1956 [1975]; 1960[1965]). Primary maternal preoccupation progressively permits the mother to identify with her infant and affords the opportunity for the infant to develop her/his own sense of self (Winnicott, 1960 [1975]). Indeed, contemporary psychoanalytic theory has accentuated the importance of sensitive affective mirroring (i.e., caregivers responding with a marked emotional display of their own, mirroring their child) and attunement to infants' emotional needs as a mechanism through which affect regulation is developed and the self is constituted in the child (Fonagy, Gergeley & Jurist, 2004).

This psychic re-organization likely begins during pregnancy; however, there has been little discussion of an endpoint postpartum. Winnicott (1956 [1975]) initially proposed maternal preoccupation to continue for a few weeks postpartum, prolonging this period to include the first months following delivery in his subsequent writing (Winnicott, 1960 [1965]). Given the

potential for variability in mothers' psychic adaptation and events in their environment, there may also be reason for variation in the duration of preoccupation. Alternatively, changes in the preoccupied state may be more dynamic throughout the postpartum period, with a potential preoccupied state that distinguishes mothers from non-mothers more generally across the lifespan. Nevertheless, insights on the duration of this period may be valuable clinically with identifying critical or sensitive periods for caregiving interventions. For instance, preoccupation normatively diminishes as a mother and her infant's needs become separate, and therefore allows the infant to separate gradually from the mother (Winnicott, 1960 [1965]). Conversely, mothers remaining highly preoccupied months after delivery may reflect either characteristics of the infant or of the mother's psychic state with potentially detrimental consequences for both mother and her developing child (Winnicott, 1960 [1965]). With this in mind, contemporary theorists have attempted to measure preoccupation with semi-structured interviews informed by Winnicottian theory: evidence suggests that maternal preoccupation peaks during the first weeks of the postpartum period but begins to show a decrease at 3 to 4 months postpartum (Kim, Mayes, Feldman, Leckman & Swain, 2013; Leckman et al., 1999). Critically, these studies have not extended beyond 3 to 4 months postpartum so it is not possible to say if maternal preoccupation with her child ever becomes fully resolved.

Neurobiological changes. Preclinical (i.e., animal) and human research also suggests that there may be significant structural and functional brain changes critical to the transition to motherhood during pregnancy and the postpartum period. Preclinical research has identified a significant role for the hypothalamus and the production of oxytocin for initiating the onset of maternal behavior (Insel & Young, 2001), as well as an adaptation of the stress and reward neurocircuitry (Rutherford et al., 2011). The medial preoptic area (MPOA) of the hypothalamus

has been noted as crucial for initiating maternal behavior; for instance, lesions to the MPOA in rats result in cessation of nest-building behaviors and a diminishment in nursing (Numan, 2007). Importantly, the MPOA may be associated with hormonal changes related to late pregnancy and parturition, triggering the onset of maternal behavior (Numan, 2007; Olazábal et al., 2013). Specifically, oxytocin, a neuromodulatory hormone produced in the hypothalamus, with receptors in the MPOA, plays a central role in uterine contraction during labour and stimulating milk discharge throughout lactation (Uvnas-Moberg & Eriksson, 1996), as well as initiation of affiliative and maternal behavior (Levine, Zagoory-Sharon, Feldman & Weller, 2007; Insel & Young, 2001). Thus, endocrine responses may trigger the onset of maternal behavior; however, rodent evidence also suggests that the maintenance of maternal behaviour may not depend entirely on endocrine responses as well as the involvement of other brain systems (Olazábal et al., 2013), including the reward system.

Animal research suggests an adaptation of the reward system as critical to the transition to motherhood such that it may be re-organized to support caretaking behavior (Rutherford et al., 2011). The reward system, also known as the mesolimbic dopamine system, is crucial for reward-seeking and incentive behaviour (Kauer & Malenka, 2007; Koob & Volkow, 2010; Wise, 2008). This dopamine pathway connects the ventral tegmental area (VTA) with the nucleus accumbens (NAc) and prefrontal cortex (PFC); and these core reward structures have been implicated in parenting (Rutherford et al., 2011). Animal research also suggests that pups have rewarding value to their mothers (Mattson & Morell, 2005), and that this dopamine system is implicated in incentive aspects of maternal behavior that drive continued maternal care (Numan, 2007). Critically, some research even suggests that pup stimulation in lactating rats may be even more rewarding than reward-inducing drugs of abuse like cocaine (Ferris et al., 2005). Thus

infant cues may be more salient than others sources of reward, converging with the hypothesized adaptation of the reward system to support maternal behavior. Notably, this dopaminergic reward system also interacts with the oxytocin system, with oxytocin receptors being located in reward-related brain regions (Olazábal & Young, 2006). Therefore, a critical interplay between these different neural systems may guide and reinforce maternal behavior (Numan & Woodside, 2010; Swain et al., 2014).

Consistent with these animal studies, an adaptation of the reward system has also been recognized as crucial for motivating caretaking behavior in humans (Swain, 2011). Recent neuroimaging evidence suggests that infants hold inherent features that elicit reward-related activation (Glocker et al., 2009; Lundstrom, 2013; although see Caria et al., 2012). These features or baby schema (i.e., characteristic physical features of infants that are thought to elicit caretaking, including big eyes, rounded cheeks; Lorenz, 1943) activated the NAc in nulliparous women, indicating the engagement of the reward system irrespective of kinship. Furthermore, research also suggests increased activation in reward-related brain regions in mothers when viewing their own versus unfamiliar infant faces during neuroimaging experiments. For instance, converging research has evidenced increased activation in reward brain regions when mothers view their own infant's face relative to an unknown infant's face (Nitschke et al., 2004; Strathearn, Li, Fonagy and Montague, 2008), including increased activation in the OFC, VTA, substantia nigra and striatum. Taken together, while infant faces may contain innate incentive features that promote caretaking behaviour through activating reward neural circuitry, this activation of the mesolimbic dopamine systems is most prominent when mothers view photographs of their own infant. Once mothers associate these (and other) rewarding cues with

their infant, the rewarding experience of caregiving is more predictable, motivating maternal behavior (Rutherford et al., 2013).

Interestingly, increased activity in reward-related brain regions has also been found in maternal samples when listening to infant cries, compared to control noises (e.g., orbitofrontal cortex (OFC), VTA, substantia nigra; Lorberbaum et al., 2002). Although this may seem counterintuitive, it may be explained by the growing literature that disentangles the broad construct of reward into the following cognitive processes: liking, wanting, and learning (Berridge, Robinson & Aldridge, 2009). Thus the dopaminergic activation described in response to infant cries may be consistent with the 'wanting' aspect of reward, motivating maternal behavior toward soothing the child (Rutherford et al., 2011). Although certain aspects of maternal care, including infant cry, may not contain an initial hedonic value (which would be considered as reward liking), mothers may still be motivated to provide care through the motivation of wanting to care for an infant and attend to their needs. This activation of reward neural circuitry in response to infant cry may also serve an adaptive function, ensuring that mothers are naturally motivated to respond to infant's signals of distress (e.g., cries), potentially facilitating infant survival.

Thus far these preclinical and human studies suggest a significant role for reward neurocircuitry in the transition to motherhood. Additional brain regions recruited in human parents also include those brain regions recruited in processing emotional valence (amygdala, cingulate, insula) and underscoring executive functions (medial prefrontal cortex; mPFC, dorsolateral prefrontal cortex; dlPFC; Gonzales, Atkinson & Fleming, 2009; Rutherford & Mayes, 2011; Swain, 2011). Furthermore, activation in these regions seem to differentiate parents from non-parents. For instance, Seifritz and colleagues (2003) reported parents, relative

to non-parents, showed greater activation of the amygdala and PFC in response to listening to infant cries – with non-parents instead evidencing greater responsiveness in these same brain regions to infant laughter. Given the role of these brain regions in emotional processing and executive functioning, these findings suggest that parents may be more responsive and regulated to infant distress. Studies employing the event-related potential (ERP) technique have also reported increased sensitivity to infant distress in mothers relative to non-mothers, where mothers have both a greater neural response to infant cries (Purhonen et al., 2008), and evidence differential neural sensitivity to varying intensities of infant distress (Proverbio et al., 2006).

Finally, it is worth noting that functional brain changes critical to the transition to motherhood may also be accompanied by structural brain changes across the postpartum period. Kim and colleagues (2010) conducted a short-term longitudinal study to examine differences in mothers' gray matter volume at 2-4 weeks postpartum and 3-4 months postpartum. Results revealed increases in gray matter volume in the PFC, and regions associated with maternal behavior and motivation (hypothalamus, substantia nigra, amygdala) across the postpartum period. However, it remains unclear whether these structural and functional brain changes associated with motherhood constitute a change in temporary state (akin with preoccupation) or a more trait neurobiological shift that continues across the lifespan. In fact, the studies that have compared mothers to non-mothers typically do so early in the transition to motherhood.

Taken together, neuroscience and psychoanalytic literature converge on there being both psychic and neurobiological changes accompanying the transition to motherhood that are necessary for sensitive and responsive maternal behavior. These changes may have evolutionary value in motivating caregiving behavior and thus promote the survival of the infant.

The Role of Maternal Experience

Although many of the psychic and neurobiological changes described thus far may begin during pregnancy, it is important to acknowledge that these changes associated with motherhood may be shaped by how a mother experiences and responds to her child throughout the postpartum period (and beyond). This is especially important to consider given that many women become mothers without prior pregnancy (e.g., through fostering or adopting their child), and that there may be significant variability in how much time mothers may spend with their child and how much prior caregiving experience they may have had.

Psychoanalytic perspective. The role of maternal experience in the transition to motherhood has been a less well-elaborated topic in psychoanalytic theory. Nonetheless, psychoanalysts, including Winnicott and Pines, have underscored the importance of actual contact with an infant in shaping maternal sensitivity and its impact on psychical processes associated with motherhood. For instance, Winnicott (1956 [1975]) suggested that non-birth mothers might enter primary maternal preoccupation comparatively to birth mothers. Thus, it may be assumed that contact with an infant may initiate biological processes that may facilitate mother's heightened sensitivity to their child (Rutherford & Mayes, 2011).

During the transition to motherhood, an interaction between psychical processes such as fantasy and reality (i.e., a mother's actual contact with her infant) occurs (Pines, 1972). Indeed, mothers' "early childhood identifications with her own mother are re-awakened and measured against the reality of her relationship to her child" (Pines, 1972, pp. 334). Thus actual experience with one's infants may allow mothers the opportunity to reflect and work through their own early psychic conflicts in becoming a mother. Moreover, mothers' progressive cathexis of the baby across pregnancy and time postpartum may enable mothers' to bond and identify with their

infant, perhaps through ongoing fluctuations in the cathexis of the infant based on dyadic experiences (Bibring, 1959; Pines, 1972; Walter & McCoyd, 2009; Winnicott; 1956[1975]).

While this cathexis of the infant may occur during multiple pregnancies, it has been suggested that it is specifically in the first pregnancy where a psychic re-organization occurs (Pines, 1972; 1982). The first pregnancy constitutes "the end of the woman as an independent single unit and the beginning of the unalterable and irrevocable mother-child relationship" (Pines, 1972, pp. 333). Thus, although intra-psychic conflict in motherhood may vary depending on mothers' own internal representations, the first-pregnancy constitutes a critical period for all mothers, as there is a re-organization of their internal representational world (i.e., 'normal crisis'; Pines, 1972). The first pregnancy may also play an important role to the state of preoccupation. It has been noted that during the three first months postpartum, primiparous mothers are more anxious and concerned for their infants' welfare in a mildly stressful situation as compared to multiparous mothers (Leckman et al., 1999; Mitchell & Stevens, 1968). Similarly, first-time compared to experienced mothers are more anxious and present a higher arousal state when interacting with their infants (Boukydis & Burgess, 1982) as well as when they are separated from their infant at birth (Seashore, Leifer, Barnett, & Leiderman, 1973). Comparably, first-time mothers, may show increased caregiving thoughts, a higher degree of preoccupation and more intrusive worry about their infants across the first months of the postpartum period as compared to experienced mothers (Kim et al., 2013). Thus considering parity as a factor in preoccupation may provide value to our understanding of this preoccupied state in primiparous mothers and how mothers may continue to sensitively respond and identify with their subsequent children. Interestingly, research in the field suggests that experienced mothers, relative to first-time mothers, tend to be more responsive to their infants (Robson & Kumar, 1980), specifically to

their infant's cries (Bernal & Richards, 1970) and to their newborn's body odors (Schaal, 1986). Perhaps mothers have already experienced primary maternal preoccupation and are therefore more attuned to infants such that it would be maladaptive, or unnecessary even, to re-enter the intensity of a first preoccupied state. However, there is a need for further research to more fully understand the interplay between primary maternal preoccupation and maternal responsiveness in primiparous and multiparous mothers.

Neurobiological perspective. Consistent with psychoanalytic literature, neuroscience research suggests that experience may shape the maternal brain and modulate maternal sensitivity and responsiveness in the transition to motherhood. With respect to brain structure, animal studies have evidenced structural brain changes in dams following increased interactions with their pups (Featherstone, Fleming, & Ivy, 2000; Fleming & Korsmit, 1996; Lonstein, Simmons, Swann & Stern, 1977). This converges with increases in gray matter volume observed across the postpartum period in human mothers that were in turn associated with maternal positive perception of their infant across this period (Kim et al., 2010).

With respect to functional brain changes, evidence of the influence of maternal experience has been sought by comparing biological and non-biological (foster) mothers when they viewed photographs of their child's faces as compared to an unknown child's face (Grasso, Moser, Dozier & Simmons, 2009). The results suggested an increased neural response (measured by ERPs) to own versus unknown infant faces in neural markers of perceptual (N100) and attentional (P300, LPP) processes, which were comparable between biological and foster mothers. Given the absence of pregnancy of this child in the non-biological maternal group, these findings suggest that experience may also modulate neural responses measured in mothers when viewing images of their child. However, it was not reported in this latter study whether

foster mothers had previous biological children, and therefore a definitive answer on the contribution of experience versus existing neurophysiological architecture shaping the maternal brain response cannot be determined. In another study of only non-biological mothers, the neural response associated with attentional processing, the P300, was also larger when these mothers viewed photographs of their own infant's face, as compared to unknown infant's face (Bick, Dozier, Bernard, Grasso & Simmons, 2013). Crucially, while there was no association between this neural response and the hormone oxytocin shortly after placement with the mother, there was a positive correlation between oxytocin levels in this maternal group and the P300 elicited when viewing their own infant's face three months after placement. Thus oxytocin may play a role in how experience may shape the maternal brain response over time.

To further understand the role of experience on the maternal brain, Bornstein and colleagues (2013) examined primiparous mothers at 3 and 6 months postpartum, also viewing their own and an unfamiliar infant face. Consistent with earlier studies, primiparous mothers showed a larger neural response (N/P600) to their own as compared to an unknown infant stimulus, although there was no difference in this neural response when measured at 3 and 6 months postpartum. Critically, this was a cross-sectional study and therefore different mothers were assessed at these two postpartum time points. Thus to more fully understand whether mothers maintain a heightened response to their infant across the postpartum period, it will be important to assess this study in the same group of mothers over time.

Finally, another approach to quantifying experience shaping the maternal brain is to consider primiparous as compared to multiparous mothers in their neural response to infant cues. Maupin and colleagues (under review) found that emotional unfamiliar infant faces elicited a greater attentional P300 neural response in primiparous mothers, relative to multiparous mothers,

at 3 months postpartum. This parity effect was not present for the P300 elicited by infant cries. These findings converge with the notion of enhanced saliency and thus attunement with infant facial cues, consistent with the enhanced maternal sensitivity that may occur with the first pregnancy. Taken together these lines of research suggest that contact with one's infant as well as prior caregiving experiences may influence psychic and neurobiological changes in motherhood.

Individual Differences and Psychopathology

How a mother adapts to the changes accompanying motherhood may have significant implications on how she will process and respond to her infant's needs – and this adaptation is unlikely to be uniform and may instead vary across mothers. The internal representation of a mother's early object relations, influenced by new relationships and experiences over time, may impact how she adapts to the changes inherent in motherhood and may affect how she subsequently experiences and responds to her infant (Ammaniti & Trentini, 2009; Pines, 1972, 1988; Winnicott, 1956 [1975]; 1960 [1965]).

Differences in mothers' internal world. As part of normal variability across mothers, individual internal object representations that contribute to the intra-psychic world may shape how mothers may experience and respond to their infant (Ammaniti & Trentini, 2009; Pines, 1972; Turrini, 1980). As underscored by object relations theory, the singular subjective early experience with the primary object may play an important role in the formation of internal objects (Ogden, 1983). Internal early object representations, although malleable to change over time, may guide individual functioning and future patterns for relational styles, and this may be particularly important in the transition to motherhood (Ainsworth, 1969; Bibring, Dwyer, Huntington & Valenstein, 1961; Pines, 1972). Given that during this transitional period a woman

is creating a mental representation of her child as well as trying to rework her own relationship with her mother, her own early experiences with the primary object may be particularly re-awakened during this stage (Pines, 1972). Thus, these early object experiences may influence how a woman adapts to the psychical changes associated with motherhood and therefore, how she responds to her infant (Pines, 1972; Winnicott, 1956 [1975]).

Critically, mothers who experienced an invasive, withholding or unattuned primary object may find it difficult to accurately respond and identify with their own infants (Winnicott, 1956 [1975]). Specifically, it has been proposed that mothers' with frustrating early object experiences may have a continued intra-psychic conflict, even after the birth of their child given these unresolved early experiences of frustration. Consequently, past conflict may be re-enacted in the present mother-infant interaction, which may manifest with mothers continuing to act out the past conflict with her primary object in her present relationship with her infant (Pines, 1972). Therefore, for these mothers, deep-rooted feelings of hostility and ambivalence may resurface during motherhood, and impact their capacity to identify and respond to their infants (Winnicott, 1956 [1975]).

The notion of early experiences influencing motherhood is echoed by attachment theory, with Bowlby (1982) stressing a reciprocal relationship between the attachment and the caregiving system (Ammaniti & Trentini, 2009). Bowlby (1969/1988) suggested that the representational models formed in early life with the primary caregiver, which may be influenced by future relationships, may also impact the new mother-infant attachment. However, others have suggested that mothers' early attachment experiences may be influenced, and even modified, by the formation of new attachment relationships that in turn impact caregiving with the infant (Sette, Coppola & Cassiba, 2015). Thus, individual differences in motherhood may

relate to mothers' current attachment but this may not be directly linked with her early attachment relationships. With this in mind, contemporary theorists have developed a semi-structured interview to assess mothers' current attachment, namely the Adult Attachment Interview (AAI; George, Kaplan & Main, 1985). This measure delivers information regarding the individuals' current attachment classification based on an adult's recollection of their experiences with their own parents: secure-autonomous, insecure-dismissing and insecure-preoccupied. Interestingly, evidence suggests that maternal individual differences as indexed by attachment classification correlates with their infant's attachment style, suggesting an intergenerational transmission of attachment (Main, Kaplan & Cassidy, 1985).

In addition to variability in these object experiences that may influence maternal responding, deviations from normality in the transition to motherhood may also be associated with mothers' psychopathology and pathological features in the mother-infant relationship (Pines, 1972). Relatedly, individuals who have experienced early frustrating experiences and intense relations with internal bad objects may be more vulnerable to the development of psychopathology (e.g., schizophrenia, Klein, 1960; drug addiction, Glover, 1956). Thus mothers who have negative internal object relations may be at a heightened risk for psychopathology, which may further impact the dyadic relationship. Nonetheless, it should be noted that there is a mixed response across psychoanalytic theorists on the extent to which maternal psychopathology might impact parenting and their child's socio-emotional development. For instance, object relations theorists such as Klein minimize the extent to which maternal deficiencies may affect their infant's socio-emotional development, whereas other psychoanalysts such as Fairbairn have highlighted maternal deficiencies as the exclusive source of psychopathology in the child (Mitchell, 1981). Finally, it is worth noting that other variables, including temperament and

genetic dispositional factors, may interact with early (and future) experiences and consequently influence the formation and development of internal representations across the life span (de Wolf, 2013; Fonagy, 2003) – further modulating existing internal relationships Taken together, a mother's own object experiences may influence variability in motherhood, amongst which difficulties and frustrating object experiences may lead to pathological features in the transition to motherhood and thus influence the emerging dyadic relationship.

Neuroscience on individual differences and psychopathology. Emerging preclinical evidence indicates that differences in the dopamine and oxytocin systems may underlie individual differences in maternal response to their infants at a neurochemical level. For instance, Champagne and colleagues (2004) found increased dopamine concentration in the NAc of dams high in licking/grooming relative to dams low in licking/grooming behaviour. Given that high-licking/grooming behaviour is a marker of enhanced maternal care in rodents, this finding suggests that differences in the dopaminergic system may underscore motivation to provide maternal care. In humans, Atzil, Hendler and Feldman (2011) found a positive correlation between NAc activation and peripheral oxytocin levels in well-adapted (i.e., synchronous), as compared to asynchronous, mothers while observing mother-infant vignettes, which was associated with their coordinated gaze, affectionate vocalization, and touch with their infant. Similarly, securely attached mothers, as compared to insecurely attached mothers, evidenced an increase in activation in reward-related brain regions (OFC, VS, mPFC) when viewing photographs of their own infants, as well as higher levels of oxytocin after a play interaction with their child (Strathearn, Fonagy, Amico & Montague, 2009). Taken together, these studies support an interaction between the dopamine and oxytocin systems in maternal behavior and their variability being important in the individual differences in maternal behavior. These

findings converge with meaningful differences in attachment classification at a neurobiological level in maternal responding to her infant.

With respect to psychopathology, a handful of human studies have begun to explore whether depression and addiction affect the maternal brain. Generally, these studies suggest infant faces and cries are less salient to depressed and substance-using mothers as compared to healthy control mothers. For instance, Laurent and Albow (2011) compared the neural responses to infant cries (familiar and unfamiliar) between depressed and non-depressed mothers. Non-depressed mothers showed increased activation in motivation and reward-related brain regions (i.e., OFC, ACC and striatum) when listening to their own infant crying as compared to an unknown infant crying or a control stimulus. In direct contrast, depressed mothers showed no differentiation in the neural response between listening to their own infant crying and the other experimental conditions. Given that infant cries may elicit a motivational incentive value in mothers (i.e., reward wanting), these findings indicate that depressed mothers may find their infant's cry less salient, which may have downstream consequences for their caretaking motivation. Notably, within the addiction domain, substance-using mothers, as compared to healthy controls, also showed reduced brain activation in response to unfamiliar infant faces and cries in sensory, emotional, and cognitive control (e.g., occipital lobes, parahippocampus, amygdala, dlPFC and ventromedial PFC) processing regions (Landi et al., 2011). These findings fit into a broader theoretical perspective of parenting and addiction that suggests a dysregulation of the reward system in addicted mothers wherein the reward system may be co-opted for habitual drug-taking behavior, rather than caretaking behavior (Rutherford et al., 2011; 2013).

Taken together, these initial studies suggest that psychopathology may decrease the saliency of infant socio-emotional signals in mothers. While these studies suggest a role for

compromised reward neural circuits, it should also be noted that the stress system also plays a role in maternal behavior (Rutherford et al., 2011, 2013). Furthermore, multiple clinical disorders may also be accompanied by a dysregulation of the stress system (Fonagy & Luyten, 2009; Sinha, 2008; Yehuda, 2001). Indeed, parenting is accompanied with increased levels of stress, and enhanced regulatory strategies are needed even in the absence of psychopathology. Therefore, individual differences in stress reactivity and regulation could also be important to consider in shaping maternal neural responding to infants. With this in mind, attachment as a construct has begun to be considered more generally as a stress regulation system, where maternal stress regulation may impact the regulatory strategies developed by the child (Nolte, Guiney, Fonagy, Mayes & Luyten, 2011).

Bridging Psychoanalysis and Neuroscience

In this review, psychoanalytic and neuroscience evidence has converged to suggest the transition to motherhood as a unique transitional period in adulthood that is accompanied by psychic and neurobiological re-organization to support the emerging dyadic relationship. Although the directionality of causal influence of neurobiological changes and psychic adaptations during pregnancy and postpartum is unknown, there may be value in considering this as a period of reciprocity between mind and brain. It may be that the increased sensitivity to infant cues characterizing the transition to motherhood bridges psychoanalytic and neuroscience perspectives.

Increased sensitivity to infant cues. Both psychoanalytic and neuroscience theory suggest heightened sensitivity to infant cues, particularly in motherhood, and that this may be encompassed into an integrative ‘signal detection model’ (Rutherford & Mayes, 2011). Rutherford and Mayes (2011) suggest that Winnicott’s primary maternal preoccupation may be

understood as part of a signal detection system, which operates through the detection of a highly salient stimulus and the allocation of resources to that stimulus. Here the stimulus or signal to be detected is the infant's affective cue, such as a cry or change in emotional expression that then guides attentional and cognitive processes. The psychic state in motherhood, such as preoccupation, may increase mother's sensitivity to detect infant signals of emotion. In turn, this may allow mothers to both create room in her psychic apparatus for her infant and to appropriately respond to her infant's needs (Rutherford & Mayes, 2011). Support for this hypothesis may be drawn from studies evidencing that mothers, as compared to non-mothers, have a heightened neural response to infant stimuli, consistent with differential sensitivity or detection of infant signals that may be shaped during this transitional period (Proverbio et al., 2006; Purhonen et al., 2008; Seifritz et al, 2003). However, longitudinal studies are still required to elucidate whether the neurobiological and psychic changes that may underscore enhanced signal detection to infant cues are present only during the early postpartum, or whether they persist in some form across the lifespan.

Given that neuroscience research has mostly focused on early stages of processing infant cues, this first step in an integrative model may at face value appear reductionist. However, it should be noted that early perceptual and attentional processes may lead to more complex meta-cognitive constructs (Gazzaniga, 2004), including mentalization (i.e., the capacity to envision own and others mental states and their associations with behavior; Fonagy & Allison 2012; Rutherford & Mayes, 2011). Indeed, a mother's capacity to mirror and be attuned to her infant's affect (potentially enabled by this enhanced signal detection to infant cues) may be associated with her capacity to mentalize about her child (Fonagy et al., 2004; Fonagy & Target, 1997). Supportive of this notion, neuroimaging research has evidenced that maternal brain regions

integral to understanding empathy and action (Rizzolatti & Craighero, 2004) are more active in response to a child's emotional expressions, and this response that is heightened when it is one's own child, with this brain activity positively correlating with maternal mentalization (Lenzi et al., 2009). This finding converges with the notion that perception of infant emotional cues may be the first stage in higher order processing that may vary from mother to mother (Amanniti & Trentini, 2009; Lenzi et al., 2009). One recent ERP study also reported that rapid neural markers of infant affective cue processing were correlated with a self-reported measure of parental reflective functioning (Rutherford, Maupin, Landi, Potenza, & Mayes, 2016). Therefore, while primary maternal preoccupation may go beyond a simple detection of infant emotional signals to incorporate processes such as maternal identification with her infant and mentalization. Signal detection may be an initial marker of this more complex process that could be empirically studied employing both behavioral and neuroimaging assessments. Impairments to maternal signal detection may be expected with psychopathology, and the neurobiological data indicating decreased salience of infant signals in depression and addiction suggests this may be the case.

Sensitivity to infant cues and reward. Neuroscience and psychoanalytic literature converge to suggest that there are changes in the investment of what is rewarding during the transition to motherhood and this may be one mechanism that underscores the enhanced sensitivity to infant cues observed in mothers as compared to non-mothers. At the level of the mind, changes in investment of libidinal energy occur across this transition (Benedek, 1959; Pines, 1972). This libidinal process of the infant, including the introjection of gratifying experiences, may allow mothers to bond and identify with their child (Benedek, 1959; Bibring, 1959; Pines, 1972). Importantly, given that maternal psychic resources are directed towards the infant in this ongoing process of libidinal investment, it may in turn allow mothers to have their

infant in mind and therefore, be more sensitive to detect their infant's socio-emotional signals. Such a notion converges with a primary maternal preoccupation framework as it highlights a change in mothers' orientation away from themselves and the world around them toward the child (Winnicott, 1960 [1965]). Critically, the adaptation of the mesolimbic reward system during pregnancy and parturition may facilitate this process to support maternal caretaking behavior (Rutherford et al., 2013; Swain, 2011). Here the rewards associated with caregiving, including infant socio-emotional cues, may be reinforced across motherhood, becoming increasingly salient to mothers (Rutherford et al., 2013). While this experience of reward may be particularly reinforced to mothers' own infant cues (Lorberbaum et al., 2002; Nitschke et al., 2004; Strathearn et al., 2008), it may also have downstream consequences in increasing the general saliency of infant signals in parents.

The role of experience. Maternal experience may play an important role in modulating sensitivity to infant cues and the mechanisms that may underscore this process. Through continuous contact with her infant, a mother's attunement to her infant's cues and her motivation for caregiving may be progressively amplified and reinforced. This may be underscored by changes in the maternal functional and structural brain across the postpartum period (e.g., Bick et al., 2013; Kim et al., 2013). A potential neurobiological mechanism through which this sensitization to infant cues may, at least in part, take place is via the dopaminergic reward system, which may be stimulated throughout the transition to motherhood. As discussed, features of infant faces may be inherently rewarding (Glocker et al., 2009), and familiarity may amplify such effects (Lorberbaum et al., 2002; Nitschke et al., 2004; Strathearn et al., 2008). Thus repeated exposure to infants may enhance caregiving motivation. Moreover, the rewards associated with parenting are likely influenced by a diverse array of neurobiological systems,

including the oxytocinergic system (Baskerville & Douglas, 2010; Strathearn et al., 2009). Given the evidence that indicates a positive correlation between foster mothers' neural response to their own infants and maternal oxytocin levels after mothers spent extended time with their child (Bick et al., 2013), the oxytocinergic system may also be implicated in the increased sensitivity and detection of infant socio-emotional cues during the postpartum period (see Kim and Strathearn, this issue).

As well as these neurobiological mechanisms, it is possible that sensitization to infant cues as a function of maternal experience may also influence mothers' primary maternal preoccupation. This can be illustrated by studies suggesting that mothers with prior child-rearing experience may not present with as high levels of primary maternal preoccupation as first-time mothers (Kim et al., 2013). Given that experienced mothers have had more exposure to infant cues and child-rearing experiences, it is possible that these mothers may have become more sensitized to infants in general and thus, may not need such increased levels of preoccupation in order to accurately respond to their child's needs early postpartum. Indeed, there is evidence suggesting that experienced, as compared to first-time, mothers may be more responsive to certain infant cues (Bernal & Richards, 1970; Robson & Kumar, 1980; Schaal, 1986). Thus it is important to consider the interplay of neurobiological and psychic processes during pregnancy and parturition.

Importantly, while this discussion supports the notion that maternal experience may modulate sensitivity to infant cues, it is worth considering that neurobiological and psychological changes that occur during pregnancy may also trigger changes in sensitivity to infant cues. However, there is still a need for research to elucidate the relationship between physiological and psychological changes that occur in pregnancy that may trigger the onset of motherhood in

humans. This may be achieved through continuous assessment of maternal hormone levels, including oxytocin, as well as non-invasive neurophysiological measures, such as EEG and neuroimaging, in conjunction with psychoanalytically informed measures, such as fetal attachment (e.g., Maternal Antenatal Attachment Scale; Condon, 1993) and reflective functioning (e.g., Pregnancy Interview, Slade, 2007). Additionally, it would be of interest to elucidate the transition to motherhood in women who do not have biological children but are sensitive and response caregivers.

Individual differences. In addition to the role of maternal experience, individual differences may play an important role in how a mother experiences and responds to her infant. One of the greatest contributions of psychoanalysis has been emphasizing individual differences in maternal responding, which may be influenced by mothers' own early experiences (Bibring et al., 1959; Pines, 1972; Turrini, 1980). Maternal attachment classification as one measure of individual differences has yielded neurobiological differences in the mesolimbic reward and oxytocin systems (Strathearn et al., 2009). However, it is worth noting that while neuroscience has begun to explore the neural correlates that may underlie differences in maternal attachment, the neural basis by which internal representations of early objects are formed remain largely unknown. A neurobiological investigation of how early representations may be formed and modified would be valuable, normatively and clinically, allowing more precise mechanisms to be identified across development that may lead to later differences in caregiving behaviour and maternal sensitivity to infant's cues.

Considering attachment as a stress regulation system (Mayes, 2006; Nolte et al., 2011; Sbarra & Hazan, 2008), a dysregulation of the stress system more generally may lead to difficulties in maternal responding, particularly in stress reactivity and regulation. This early life

stress may have consequences for stress regulation across generations. While maternal care plays a crucial role in mediating the regulation of their offspring's own HPA axis (Gunnar & Donzella, 2002), early life stressors in caregiving, including maternal stress, are associated with child's HPA axis alterations (Graham, Heim, Goodman, Miller & Nemeroff, 1999; Matthews, 2002; Heim, Newport, Mletzko, Miller & Nemeroff, 2008). In turn, dysregulations of the HPA axis across development may also impact an individual's stress regulation strategies, which may have detrimental consequences for maternal care (Mayes, 2006; Nolte et al., 2011). Taken together, these different lines of research suggest that early adversity may shape the attachment system, leading to dysregulation of the stress system across development. Such a dysregulation may have lasting consequences, including how mothers detect and respond to their own and their infants' emotional needs. The clinical relevance for these early life effects influencing later maternal behavior may be valuable in probing the pathway to how maternal psychopathology may impact the dyadic relationship, given that a dysregulation of the stress system may accompany multiple clinical disorders (Fonagy & Luyten, 2009; Nolte et al., 2011; Sinha, 2008; Yehuda, 2001). However, more research is still needed to examine the impact of stress reactivity and regulation on maternal sensitivity as a function of attachment and psychopathology. Concurrently, there is a necessity for research to elucidate how stress during pregnancy may impact both psychic and neural correlates associated with the transition to motherhood. Notably, preclinical studies have evidenced that prenatal stress may directly alter maternal care and have an enduring effect on the infant and mother's brain (Champagne & Meaney, 2006; Peña, Monk & Champagne, 2012). This represents an important next step for the human literature.

Conclusion

In conclusion, literature from psychoanalysis and neuroscience underscores the importance of the transition to motherhood as a unique transitional period in adulthood. Although psychoanalysis and neuroscience employ different levels of abstraction and methodology, there is sufficient synergy and convergence that warrants their joint consideration. We proposed that both neurobiological and psychic re-organization may occur in order to meet the demands of motherhood, which may be considered as an enhanced signal detection of infant cues. Critically, maternal experience and a host of individual differences relevant to early experiences and psychopathology may influence the transition to motherhood. However, this work demands greater consideration empirically in the exploration of psychic and neurobiological changes in women transitioning to the maternal role, as well as being informed by other theoretical perspectives, including anthropological and sociocultural perspectives. Understanding the transition to motherhood may be of great clinical value, providing insight into where dyadic relationships may be compromised and mothers struggle in their caregiving role, which may have lasting consequences for parent and child development.

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