

# *Psychological and Psychophysiological Considerations Regarding the Maternal–Fetal Relationship*

Janet A. DiPietro\*

*Department of Population, Family and Reproductive Health, Johns Hopkins University, 615 N. Wolfe St, E4531, Baltimore, MD 21205, USA*

The earliest relationship does not begin with birth. Pregnant women construct mental representations of the fetus, and the feelings of affiliation or ‘maternal–fetal attachment’ generally increase over the course of gestation. While there is a fairly substantial literature on the development and moderation of psychological features of the maternal–fetal relationship, including the role of ultrasound imaging, relatively little is known about the manner in which maternal psychological functioning influences the fetus. Dispositional levels of maternal stress and anxiety are modestly associated with aspects of fetal heart rate and motor activity. Both induced maternal arousal and relaxation generate fairly immediate alterations to fetal neurobehaviors; the most consistently observed fetal response to changes in maternal psychological state involves suppression of motor activity. These effects may be mediated, in part, by an orienting response of the fetus to changes in the intrauterine environment. Conversely, there is evidence that fetal behaviors elicit maternal physiological responses. Integration of this finding into a more dynamic model of the maternal–fetal dyad, and implications for the postnatal relationship are discussed. Research on the period before birth affords tremendous opportunity for developmental scientists to advance understanding of the origins of the human attachment. Copyright © 2010 John Wiley & Sons, Ltd.

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\*Correspondence to: Janet A. DiPietro, Department of Population, Family and Reproductive Health, Johns Hopkins University, 615 N. Wolfe St, E4531, Baltimore, MD 21205, USA. E-mail: jdipietro@jhsph.edu

## INTRODUCTION

The connection between the pregnant woman and her developing fetus is perhaps the most profound but enigmatic of all the human relationships. Speculation about its nature has been largely relegated to the realm of folklore, literature, and cultural beliefs. The initial academic consideration of this topic was principally psychodynamic in orientation. Empirical interest in the maternal psychological orientation towards the pregnancy and fetus began to emerge in earnest during the 1960s. In part, this research area reflects a downward application of constructs developed to characterize maternal–infant relationships, including attachment, to the period before birth. However, this period of human development is unlike any other because the physiological relationship between the pair is paramount and inextricable. This raises the possibility that variation in one may alter the trajectory of development in the other, with implications that extend beyond parturition.

Technological advances have opened a window on the intrauterine environment, affording the opportunity to characterize the interplay between maternal emotions, maternal and fetal physiology, and fetal behavior in a manner that did not previously exist. The emerging knowledge base demonstrates the intricate nature of this relationship, including evidence of a bi-directionality. This review will focus on both the psychological and psychophysiological nature of the maternal–fetal relationship and offer speculation on promising avenues for continued examination of this relatively new field of study.

### *Psychological Considerations*

There is a fairly sizable body of literature examining maternal, and occasionally paternal, feelings of affiliation or affection towards the fetus. Research findings in this area, generally labeled ‘maternal–fetal attachment’ are summarized in two reviews that detail 63 articles published prior to 2003 (Cannella, 2005) and from 2000 to 2007 (Alhusen, 2008). Several instruments have been developed to explicitly measure the construct (Condon, 1993; Cranley, 1981; Muller, 1993), although related items are often contained within other scales that focus on pregnancy stress or anxiety.

Commonly measured components of maternal–fetal attachment scales include preoccupation with thoughts about the fetus, maternal interaction with the fetus (i.e. talking to or palpating the abdomen to elicit a fetal response), affective valence of feelings towards either the fetus or pregnancy, and the degree to which women report that they modulate their behavior or diet to foster fetal well-being. In general, maternal to fetal attachment increases as gestational age advances (Lerum & LoBiondo-Wood, 1989; Reading, Cox, Sledmere, & Campbell, 1984), and this is often suggested to be linked to increased perception of fetal movements. Randomization into an intervention consisting of asking women to engage in routine periods of fetal movement counting using standard obstetrical methods resulted in increased reporting of maternal–fetal attachment when compared with women who were not instructed in these techniques (Mikhail, Freda, Merkatz, Polizzotto, & Merkatz, 1991), suggesting that focused awareness of the fetus as a separate individual may indeed be contributory. Attempts to link the strength of maternal–fetal attachment to specific maternal psychological or demographic characteristics have been generally unsuccessful (Cannella, 2005), and there is significant inconsistency in research on factors that

may influence the psychological relationship between mother and fetus (Van den Bergh & Simons, 2008).

### *Fetal Imaging and Maternal–Fetal Attachment*

The manner in which the introduction of real-time ultrasound to obstetrics in the late 1970s changed the psychological landscape of pregnancy cannot be overstated. The potential impact of ultrasound on maternal to fetal attachment was discussed shortly after ultrasound was introduced to clinical obstetrics with the description of two case reports published in the *New England Journal of Medicine* (Fletcher & Evans, 1983). A flurry of letters followed arguing the advantages and disadvantages of this phenomenon. Twenty-five years later, the medical and diagnostic use of ultrasound has been disassociated from the simple viewing capability as facilities offer imaging services as a way for parents to ‘connect’ with their fetus. The ability to visualize, photograph, and videotape the fetus, initially with 2-D ultrasound and now with 3-D ultrasound with a time component (i.e. 4-D), has allowed parents to extend the documentation of a child’s development back from birth to the second post-conceptional month (Hata, Dai, & Marumo, 2009). Sonogram photos routinely regale refrigerators and are toted in wallets and purses. The consequences of the pervasiveness of fetal imaging has altered the way that the fetus is perceived both within the maternal–fetal relationship as well as in medicine and the broader society (Stormer, 2003).

A number of studies have indicated that viewing a fetus on ultrasound confers at least a short-term maternal psychological benefit including reduction in anxiety following a reassuring sonogram (Zlotogorski, Tadmor, Rabinovitz, & Diamant, 1997) and enhanced ability to mentally image the fetus (Ji *et al.*, 2005). There is some evidence that sonograms can also facilitate maternal–fetal attachment, at least in the short term (Pretorius *et al.*, 2006). However, there is no evidence for a shift in levels of maternal–fetal attachment when studies that collected maternal report measures of their perceptions of their fetuses as described above are compared before and after ultrasound became a routine component of obstetrical care (Levine, Zagoory-Sharon, Feldman, & Weller, 2007). It is also clear that maternal feelings of attachment increase over the course of gestation regardless of whether an ultrasound was done (Kemp & Page, 1987; Phipps & Zinn, 1986). A number of recent studies have been directed at determining whether 3-D/4-D ultrasound generates a greater psychological impact than 2-D ultrasound. Results have been conflicting with some reporting that 3-D/4-D images have greater psychological impact (Ji *et al.*, 2005), but others have not (Lapaire, Alder, Peukert, Holzgreve, & Tercanli, 2007; Rustico *et al.*, 2005; Sedgmen, McMahon, Cairns, Benzie, & Woodfield, 2006). Discrepancies may be attributed, in part, to differences in whether the emphasis on outcomes is focused on maternal feelings of affiliation towards the fetus or simply being able to construct a clearer mental representation.

Although ultrasound provides an opportunity to visualize the physical features and behaviors of the fetus, parents also develop representational models of more intrinsic characteristics of fetal personality (Zeanah, Zeanah, & Stewart, 1990). Data collected using temperament scales developed for infancy but modified for administration to expectant parents show stability in both maternal and paternal projections of fetal temperament during the third trimester and these extend into the newborn period (Zeanah, Keener, Stewart, & Anders, 1985). An interview-based assessment, the Working Model of the Child, provides more

comprehensive information about the underlying characteristics and affective tone of the parental representation of the fetus. Pregnant women who provided a balanced view of the fetus, as opposed to a disengaged or distorted perception, were significantly more likely to have infants classified as securely attached at 12 months (Benoit, Parker, & Zeanah, 1997).

### *The Prenatal Hormonal Milieu and Maternal–Fetal Attachment*

Very little is known about the contributory influence of the shifting prenatal neuroendocrine environment on maternal psychological adaptation to pregnancy or early maternal behavior. A prime candidate for a potential mediating role is oxytocin, a neuropeptide with a well-established link to affiliative and parental behaviors in a number of animal models (Insel, 1993). A prospective study found no relationship between maternal–fetal attachment and either first or third trimester levels of oxytocin in human pregnancies, but women who displayed a pattern of increasing oxytocin from the first trimester through the first month postpartum had reported higher levels of maternal–fetal attachment in pregnancy (Levine *et al.*, 2007). In contrast, no significant associations between maternal–fetal attachment and other steroids, including estradiol, progesterone, testosterone, and cortisol, during pregnancy were detected in another study (Fleming, Ruble, Krieger, & Wong, 1997). However, first trimester levels of oxytocin and the rise in the estradiol/progesterone ratio during pregnancy were positively related to stronger early postpartum maternal attachment behaviors and feelings, respectively, in those cohorts (Feldman, Weller, Zagoory-Sharon, & Levine, 2007; Fleming *et al.*, 1997). It is clear that there are significant opportunities to better understand the linkage between the neuroendocrine milieu of pregnancy, the growth of affiliative feelings toward the fetus during pregnancy, and the ultimate impact of both on early parenting behaviors and attachment.

### *Psychophysiological Considerations*

In the 1930's, Sontag and colleagues at the Fels Institute began perhaps the earliest systematic scientific inquiry into factors that influence the development of the human fetus, including those provided by the maternal psychological and physical environment (Sontag & Richards, 1938). Although their methods of access to the fetus were fairly primitive, many of the questions they posed then remain active areas of research today. Technological advances in our ability to view and monitor the fetus since that time allows greater reach into the uterus. The traditional obstetrical literature, and the sub-speciality of maternal–fetal medicine in particular, has detailed the complex interface that links the developing fetus to the pregnant woman with emphasis on the pathophysiology of pregnancy. However, study of whether and how normal variation in maternal psychological state may be transduced to the fetus has traditionally been investigated within developmental, psychophysiological, or psychobiological frameworks.

### *Fetal Responsivity to Maternal Psychological State*

There have been naturalistic observations of fetal heart rate or motor responsivity to episodes of maternal alarm, including maternal distress following a fall

(Hepper, 1990), an earthquake (Ianniruberto & Tajani, 1981), and sounding of an air raid alarm during the Gulf War (Yoles, Hod, Kaplan, & Ovadia, 1993). Note that these anecdotal reports persisted through the 1990s, illustrating the lack of systematic scientific study in this area until fairly recently. Research methodology in this area tends to rely on either observation of correspondence between measures of maternal and fetal functioning under undisturbed, baseline conditions, or observation of changes in fetal neurobehavioral functioning following experimental manipulation of maternal psychological state. Fetal neurobehaviors refer to measurable activities of the fetus that are known to be linked to neural development. This essentially reflects a downward extension of the neurobehavioral constructs first developed and applied to the newborn. Fetal neurobehavioral parameters include heart rate and heart rate variability, fetal motor activity, and fetal behavioral state, which is a manifestation of the developing interrelationship between fetal heart rate and motor activity. More detailed information on fetal neurobehavioral development and its putative nervous system origins can be found elsewhere (DiPietro, 2005). Unlike psychological assessments of maternal–fetal interaction which can be collected at any time during pregnancy, assessments of maternal–fetal physiological interaction has technological constraints related to the ability to adequately monitor the fetal heart and behavior. In addition, fetal neurobehavioral development is relatively immature through at least the first half of pregnancy. Thus, most of the studies described in the remainder of this section occurred after 24 weeks gestation.

Maternal dispositional indicators of anxiety or perceived stress, measured through self-report, have been linked to higher levels of fetal motor activity (DiPietro, Hilton, Hawkins, Costigan, & Pressman, 2002; Field *et al.*, 2003; Van den Bergh *et al.*, 1989), greater variability in fetal heart rate (DiPietro *et al.*, 2002), and state-specific alterations to both (Groome, Swiber, Bentz, Holland, & Atterbury, 1995; Sjostrom, Valentin, Thelin, & Marsal, 2002) commencing in the second half of gestation. However, self-reported psychological trait or state parameters have not been closely linked to variation in maternal physiological parameters, such as cortisol (e.g. Petraglia *et al.*, 2001; Urizar *et al.*, 2004). As a result, studies that rely solely on maternal report provide limited opportunities to understand the potential mechanisms that may mediate these observations.

In one of the first studies to deliberately manipulate maternal psychological state to observe a fetal response, fetal tachycardia was elicited by a series of experimental conditions ranging from a loud, unexpected sound to deceiving women that their fetus was inadequately oxygenated (Copher & Huber, 1967). A less threatening stimulus—a tape recording of a crying infant—generated a decelerative fetal heart rate response in anxious, but not in non-anxious or depressed women (Benson, Little, Talbert, Dewhurst, & Priest, 1987). To date, there are three reports of fetal responses to maternal exposure to the Stroop Color Word task, an experimental cognitive challenge that reliably evokes a robust sympathetic response. These include increased variability in heart rate concomitant with suppression of motor activity (DiPietro, Costigan, & Gurewitsch, 2003) and increased fetal heart rate in fetuses of women with high trait anxiety or depression (Monk *et al.*, 2000; Monk *et al.*, 2004) at or near 36 weeks gestation. Maternal viewing of a labor and delivery documentary at 32 weeks gestation by 136 pregnant participants was associated with a decrease in fetal heart rate variability but also fetal motor suppression (DiPietro, Ghera, & Costigan, 2008). However, induced maternal relaxation, also evaluated at 32 weeks gestation ( $n = 100$ ) and effected through the use of guided imagery audiotape, yields

similar fetal consequences, including increased fetal heart rate variability and suppressed motor activity, although decreased fetal heart rate was also observed (DiPietro, Costigan, Nelson, Gurewitsch, & Laudenslager, 2008; DiPietro, Ghera, & Costigan, 2008). An earlier, small study ( $n = 10$ ) found no effect on fetal motor activity in response to maternal viewing of a labor and delivery film (Van den Bergh *et al.*, 1989).

### ***Potential Mechanisms of Maternal to Fetal Transduction***

Understanding of how changes in maternal psychological state generate a fetal response remains limited. Because there are no neural connections between the pregnant woman and fetus, all observed associations must be mediated by other pathways. Baseline maternal and fetal heart rate are strongly correlated, whether averaged over 24 h (Patrick, Campbell, Carmichael, & Probert, 1982) or 50 min intervals (DiPietro, Irizarry, Costigan, & Gurewitsch, 2004). There is evidence of a circadian rhythm in fetal heart rate such that intervals of slowest heart rate occur in the middle of the night (Patrick *et al.*, 1982), but this does not appear to be affected by maternal sleep states per se (Hoppenbrouwers *et al.*, 1981). However, there is no evidence that maternal heart rate directly influences fetal heart rate when correspondence is examined using time-dependent analytical methods (DiPietro *et al.*, 2004; Van Leeuwen *et al.*, 2003). The most commonly proposed explanatory mechanisms for observations of maternal influences on fetal neurobehaviors involve single or joint activation of either the sympathetic arm of the autonomic nervous system and/or the hypothalamic-pituitary-adrenal axis (HPA). There is some evidence to support each of these possibilities. For example, maternal skin conductance reactivity to both the Stroop and a labor and delivery film has been mildly associated with the degree of fetal motor responsivity to each (DiPietro *et al.*, 2003; DiPietro *et al.*, 2008). The degree of fetal heart rate reactivity has also been associated with the maternal blood pressure response to the Stroop (Monk *et al.*, 2004). With respect to the HPA axis, higher levels of maternal salivary cortisol have been significantly correlated with higher levels of fetal motor activity in two studies (DiPietro, Kivlighan, Costigan, & Laudenslager, 2009; Field, Diego, Hernandez-Reif, Gil, & Vera, 2005).

Nonetheless, the literature exploring the manner in which maternal psychophysiological alterations affect the fetus is small and leaves many unanswered questions. In general, limited correspondence has been shown between the magnitude of a maternal autonomic response and the magnitude of the fetal neurobehavioral response. When significant correlations have been detected, these tend to be small in magnitude and can explain only a small proportion of the shared variance. In addition, the pervasive fetal response of suppression of motor activity to a number of different maternal manipulations, including both induced arousal and relaxation, is curious. As the fetal response tends to be observed soon, sometimes almost immediately, after the onset of a maternal response to the manipulation, this excludes full expression of an HPA axis response. Fetal responses have also been observed within seconds of the maternal stimulation in studies of sensory capacities, including maternal postural changes (Lecaneut & Jacquet, 2002) and auditory stimuli (Groome *et al.*, 2000) at term. Together, this pattern of findings has resulted in speculation concerning indirect mediation of physiological processes. Specifically, we suspect that at least the initiation, if not the maintenance, of the fetal response to some maternal manipulations may be mediated by fetal perceptual detection of changes in the

intrauterine milieu. Sounds generated by maternal heart rate, vasculature, and the digestive tract are prominent in the uterine auditory environment (Querleu, Renard, Boutteville, & Crepin, 1989).

The concept of a fetal orienting response to intrauterine changes has also been proposed in non-human primate models (Novak, 2004). It is possible that sudden maternal psychophysiological shifts elicit phasic responses that include a rapid sensory-mediated component as the fetus detects a change, followed by a secondary response with more complex neuroendocrine or autonomic input that may account for more chronic activation. A certain degree of fetal neurological maturation would be requisite for such a response; based on observations of the trajectory of the neurobehavioral development across a number of domains, such a response pattern would be most likely to attain a mature level of function between the 28<sup>th</sup> and 32<sup>nd</sup> week of gestation.

### *Maternal Responsivity to Fetal Behavior*

The psychophysiological studies reviewed so far have approached the maternal–fetal relationship as a unidirectional phenomenon (i.e. the fetus is a passive recipient of maternal direction). This stage of inquiry into the maternal–fetal relationship parallels the era in developmental science when the infant and child were viewed as the malleable targets of parental care. In 1968, a seminal paper by Richard Bell (Bell, 1968) introduced the now well-established construct that the relationship between parent and infant is bidirectional and that constitutional variation in infants elicits differential behavior in parents. Animal models in which offspring help shape the development of the maternal nervous system have been offered in rodents, such that the reproductive experience fosters growth in maternal neural structures that foster offspring survival, with applicability to functions that extend beyond maternal care (Kinsley, 2008).

Over 70 years ago, Fels Institute investigators speculated that the increased intensity of fetal motor activity with advancing gestation stimulated the coincidentally observed increase in maternal basal metabolic rate (Richards, Newbery, & Fallgatter, 1938). More recently, our work has identified a fetal effect on the maternal nervous system by applying time series analytical methods to examine the temporal relationships between the maternal physiological parameters and fetal neurobehavioral measures in 1 s intervals for periods of 50 min at monthly intervals from 24 weeks gestation through term. The analysis revealed a significant relation between maternal skin conductance, an indicator of sympathetic activation, and fetal motor activity. While this finding was not unexpected, its directionality was certainly unpredicted. Specifically, fetal movements, which most frequently occur in the absence of maternal perception, stimulate a small rise in maternal skin conductance following a temporal lag of 2–3 s (DiPietro *et al.*, 2004). Neither the magnitude nor the temporal characteristics of the fetal motor activity–maternal skin conductance association changed during gestation. Moreover, there was significant stability within individual pairs in the magnitude of this relationship, indicating that this aspect of fetal activation of the maternal nervous system may be a stable characteristic of individual maternal–fetal pairs, with potential implications for postnatal interaction.

These findings were replicated on a second sample of maternal–fetal pairs drawn from a South American population of different sociodemographic and ethnic background than the original U.S.-based sample, suggesting that fetal stimulation of the maternal sympathetic nervous system may be an intrinsic

feature of human gestation (DiPietro *et al.*, 2006). Fetuses move, on an average, approximately once per minute during the second half of the pregnancy (Manning, Platt, & Sipos, 1979; Nasello-Paterson, Natale, & Connors, 1988). Thus, despite the ubiquity of the stimulus, the lack of change in the nature of this association during gestation suggests that women do not physiologically habituate or become desensitized to fetal movement.

### *Towards an Integrative Model*

The fetus is increasingly regarded as an active agent in both its own ontogeny and pregnancy outcomes (Challis *et al.*, 2001; Visser, 2004). Fetal behaviors can maximize intrauterine environmental adaptation, generate epigenetic shaping of the sensory, skeletal, and nervous systems, and provide preparation for successful transition to the postnatal environment (Challis *et al.*, 2001; Prechtl, 1984; Smotherman & Robinson, 1996; Visser, 2004). In turn, there is mounting evidence that features of maternal psychophysiological functioning contribute to the developmental context of the fetus. Although the reports of maternal to fetal signal transduction in response to an experimental manipulation described above are fairly recent and novel findings, all subscribe to a relatively simple unidirectional orientation in which influence flows from pregnant woman to fetus. Thus, research into the dynamic processes that direct dyadic interaction within the maternal–fetal pair remains in its ‘infancy’, and understanding of these processes lags well behind those of postnatal interaction. Part of this is related to the challenges inherent in conducting fetal research, which restricts the pool of investigators who conduct this work. However, developmental science has historically seen a downward extension of theories, constructs and research questions from later periods of development to earlier ones. Journals devoted to infant research did not emerge until the late 1970s. Over the past decade, there has been increasing empirical documentation of dyadic coherence or synchrony in both physiological and behavioral processes in early infancy (Feldman, 2006; Harrist & Waugh, 2002; Thompson & Trevarthan, 2008). Comparative models have begun to serve as a basis for forming a more integrative theory of early attachment (Lickliter, 2008).

Although there is much basic empirical work remaining before understanding of the complex interaction between pregnant woman and fetus is complete, it is not too early to consider the broader context of human development in which this emerging information is integrated. For example, the periodic sympathetic surges women experience in response to fetal motor activity, as described above, may contribute to the observed decrements in cognitive performance observed during pregnancy (Buckwalter *et al.*, 1999; De Groot, Adam, & Hornstra, 2003) by interfering with parasympathetic processes that are required for maintenance of attention. In turn, the coincident dampening of maternal responsivity to external physical and mental challenges during pregnancy (Barron, Mujais, Zinaman, Bravo, & Lindheimer, 1986; Kammerer, Adams, Von Castelberg, & Glover, 2002; Matthews & Rodin, 1992) may benefit increased awareness and responsivity to internally generated signals. Thus, periodic sympathetic surges instigated by fetal activity may serve as a signaling function to entrain maternal arousal patterns to the behavior of the fetus in preparation for the consuming demands of newborn care. Among individuals, those maternal–fetal pairs with relatively low levels of this aspect of synchrony, either because the fetus is less active or the mother less sensitive, may experience less early postnatal interactional success than pairs with moderate or higher levels of coherence. This variation, in turn,

may have implications for subsequent maternal and infant behavior and affiliation. Thus, relatively small levels of variation in features of the maternal–fetal relationship may be magnified as development proceeds.

## CONCLUSIONS

It is clear that the earliest relationship does not begin with birth. Psychological maternal–fetal attachment commences fairly early in pregnancy and increases over gestation, culminating in the birth of an infant. There are indications that changes in pregnancy hormones may correspond to maternal psychological adaptation to pregnancy and newborn care, but there is much to be learned in this regard. Maternal psychological functioning can be transduced to the fetus, although the mechanisms that mediate this are unclear. However, it is not accurate to regard the effects of induced maternal psychological stress as damaging to fetal neurobehaviors, since both maternal relaxation and arousal produce similar consequences. Moreover, the consequences of either suppressing or increasing fetal motor activity within the larger context of a dyadic model are unknown. Extending these experimental findings to features of daily life, the end result might even be that pregnant women who express greater psychophysiological reactivity to events or circumstances in their daily environment provide greater experiential conditioning of the fetal nervous system with positive consequences for development. In addition, while the uterus is the developmental niche of the fetus, it has become clear that the fetus is also an active inhabitant of that niche. There is tremendous opportunity for the developmental scientists to characterize the manner in which the fetus affects the pregnant woman, and the nature and contribution of maternal–fetal physiological synchrony to both individual and dyadic development of mothers and infants after birth.

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