THE DEVELOPMENT OF MOTHER-INFANT COMMUNICATION THROUGH TOUCH AND GAZE PATTERNS IN DEPRESSED AND NON-DEPRESSED BREAST- AND BOTTLE-FEEDING DYADS

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Nancy Aaron Jones, Department of Psychology, and has been approved by the members of her supervisory committee. It was submitted to the faculty of The Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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ABSTRACT

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The present study examined developmental changes in the establishment of mother-infant tactile and visual communication within depressed and non-depressed breast- and bottle-feeding dyads. 113 (30 depressed, 83 non-depressed mothers) mother-infant dyads participated at the 1-month visit and 87 dyads returned at the 3-month lab visit. Maternal mood status was assessed. EEG recordings were taken from the infants at mid-frontal, central, parietal and occipital sites. Mothers and their infants were videotaped during a 5-minute feeding. The feeding session was coded for touch and gaze, utilizing coding scales similar to those of Polan and Ward (1994) and Moszkowski and Stack (2007). Infant self-touch significantly predicted infant EEG asymmetry scores. Non-depressed and depressed breast-feeding mothers displayed more affectionate touch while depressed bottle-feeding mothers displayed an absence of touch.

DEDICATION

For my brother, whose presence taught me love and friendship and whose absence has taught me strength and courage.

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I.INTRODUCTION

1. Maternal Depression affects infant temperament and brain development

As the transition from pregnancy to motherhood is so rapid, it can leave many new mothers feeling overwhelmed. In fact, according to the U.S. Health and Human Services, depression is thought to affect 13% of pregnant women and new mothers each year. EEG studies have been used to establish links between the affect and physiology of people suffering from depression. Typically, EEG patterns exhibited by depressed adults demonstrate particular trends which can help psychologists identify those who are susceptible to depression. EEG studies have linked depression to left hemispheric activation in which the left frontal hemisphere is thought to reflect the lack of approach motivation. Greater EEG power in the left hemisphere actually reflects hypoactivation of left frontal region and EEG patterns in this area have been associated with apathy, a common depressive symptom (Field, Fox, Pickens, & Nawrocki, 1995). In a study conducted by Field and colleagues, EEGs of adolescent mothers showed relative right frontal asymmetry (greater right due to decreased left activity) in 70% of the depressed sample whereas among the non-depressed group only 20% displayed relative right frontal asymmetry. Because depression is not uncommon in new mothers, the effects of maternal depression on the neonate are of great interest to researchers. It has been estimated that children of depressed parents are 2-3 times more likely to become depressed than peers of the non-depressed mothers (Weissman, Warner, Wickramaratne, Moreau, & Olfson, 1997). For instance, depressed mothers are more likely to have withdrawn interactive styles and their infants are more temperamentally reactive when compared to non-depressed dyads (Field, Diego, & Hernandez-Reif, 2009). Further brain development is protracted in infancy, particularly in the frontal lobes, which may provide risk to those infants with depressed mothers or alternatively may provide the opportunity to intervene to deflect the development of atypical brain activation patterns in these infants' predispositions.

Negative environmental stressors are logically thought to impair the normal development of the infant brain Researchers have identified infancy as a critical period of development marked by rapid neural and physical changes. During the first two years of a child's life the brain will create more synaptic connections as well as mylenation of axons (to speed up the transfer of information including within ipsalateral sites as well as across the corpus collosum) (Bell & Fox, 1992) than during any other period of development. Developmental theorists such as Piaget (1954) acknowledged the interplay between an organism and its environment, proposing that the developing organism changes in accordance with its environment. More contemporary research has focused on establishing physiological and behavioral links between the infant and the environment as well as links to the development of the brain in typical and atypical groups. Other studies have established physiological associations between maternal depression and infant brain development and have shown that infants of the depressed mothers showed significant relative right frontal asymmetry early in infancy (Field, Fox, Pickens, & Nawrocki, 1995). Compared to infants of non-depressed mothers, even at 1 week of age, infants of depressed mothers tend to exhibit less left hemispheric activation (Jones, Field, fox, Lundy, & Davalos, 1997; Jones, Field, Fox, Davalos, & Hart, 1998) The predisposition for infants of depressed mothers to display lateralized patterns of EEG asymmetry distinct from those of non-depressed groups has been documented in infants from the newborn period to 12 months (Diego, Field, Hernandez-Reif, Cullen, Schanberg, & Kuhn, 2004; Diego, Field, Jones, & Hernandez-Reif, 2006; Jones, Field, and Almeida, 2009).

Researchers have proposed that the prenatal environment may contribute to depression-like symptoms and EEG asymmetry patterns exhibited in infants. Elevated levels of stress hormones during pregnancy may in turn affect the child's hormone levels (Lundy, et al., 1999). Results of a prenatal depression study conducted by Lundy and colleagues (1999) found that women who suffer from prenatal depression report lower fetal attachment and urine samples showed higher levels of cortisol, norepinephrine, and reduced levels of dopamine than their non-depressed peers. Similar to their depressed mothers, their infants also had elevated levels of cortisol and norepinephrine and reduced levels of dopamine and serotonin (Diego, Field, Hernandez-Reif, Cullen, Schanberg, & Kuhn, 2004; Field et al., 2004; Field et al., 2008). The prenatal environment of the depressed mother may contribute to the infant's temperamental disposition that predisposes the infant to a depresso-genetic style (Goodman, 2003) and post-birth infants exposed to this environment may "mimic" the depression symptoms of their mother.

While infants cannot themselves be depressed, findings from an adult study showed that patients who are previously depressed and considered in remission still exhibit a propensity for withdrawal-type emotions along with the left frontal hypoactivation patterns associated with depression (Henriques & Davidson, 1990) and not obtained in never depressed adults. Further, studies have demonstrated the relative temporal stability of EEGs and thus support the idea that the EEG can be utilized as a state-independent marker of temperament/personality style (Henriques & Davidson, 1990; Jones, 1995; Vuga, Fox, Cohn, Kovacs, & George, 2008). Collectively, reviews by Fox, Calkins, and Bell (1994) & Fox et al. (2007) reported on a series of studies that demonstrated that EEG patterns remain temporally stable even for normally developing infants. Logically one can surmise that the adult brain is not as malleable as the infant brain and stable asymmetry patterns reflect a dispositional susceptibility to depression. However infant brains are believed to garner more plasticity with developmental predispositions, making trajectories of development partially dependent on the infant's environment.

Greenough's model of neural plasticity (Greenough & Black, 1992) explains his idea of "experience expectant" plasticity in which the development of the infant brain is pre-programmed in anticipation of specific developmental milestones, such as the development of motor skills in anticipation of locomotion. The infant brain is plastic and the temperamental depression disposition can be positively affected by the quality of mother-infant communication because of a second plasticity, "experience-dependent" plasticity which refers to the exclusive experiences in which the development of the infant’s brain is affected by individual experiences. Environmental interactions such as interpersonal exchanges alter development (Seigel, 1999) and thus early interventions utilized with depressed dyads and aimed at improving mother-infant communication through the modification of behavior have the potential to attenuate future depression in her infant. For instance, EEG research conducted by Fox and colleagues found that within a group of 4-month-old infants who exhibited EEG asymmetry a little over 25% exhibited social reticence at 4 years of age. The remainder of the group who did not remain behaviorally inhibited across infancy and early childhood may have been exposed to experiences which positively influenced their temperamental patterns (Fox, Henderson, Rubin, Calkins, and Schmidt, 2001).

2. Importance of mother-infant communication

Mother- infant communication is critical to bonding of the dyad. However, because infants lack verbal communication skills, mothers rely on other forms of communication with their infant to bond and establish the ability to sense the emotional and physical needs of her infant. During the infant's nonverbal phase, touch and gaze are the primary forms of mother-infant communication. During this period, patterns of mother-infant synchrony are established and become essential for a trajectory of effective mother-infant communication. Feldman (2007) contends that the quality of mother-infant synchrony lays the foundation for intimacy competence which extends throughout life. Mother-infant synchrony is a critical component of mother-infant communication, if mother-infant synchrony is not established efficient communication across development is hindered as well.

Mothers who effectively communicate with their infants are able to sense their infants' needs, soothe their infants more readily, and report less overall stress from parenting and stronger feelings of attachment to their infants (Mezzacappa & Katkin, 2002). Dyads who touch each other more frequently also exhibit less intrusive interactive styles (Moszkowski, Stack, Girouard, Field, Hernandez-Reif, & Diego, 2009). Preterm infants who receive frequent, affectionate maternal touch have more optimal developmental outcomes at 1 year of age (Ferber, Feldman, & Makhoul, 2007). One theory to explain why touch has such as positive impact on the mother-infant dyad specifically focuses on the release of hormones during mother-infant interactions.

The role of the oxytocinergic bonding pathway has been proposed to play a role in mother-infant bonding (Feldman, Weller, Zagoory-Sharon, & Levine, 2007) which is also intimately related to mother-infant communication. Oxytocin is released through somatosensory interaction, primarily touch, gaze, and smell (Matthiesen, Ransjö-Arvidson, Nissen, & Uvnäs-Moberg, 2001). Thus, touch and gaze not only allow effective mother-infant communication, but these behaviors also release hormones in both the mother and infant which strengthen the attachment between mother and child.

Few human studies have measured oxytocin levels in mothers and infants during feeding sessions, but those studies that have been conducted support the oxytocinergic bonding theory (Feldman, et al., 2007). Matthiesen and colleagues (2001) measured maternal oxytocin levels from the birth of the infant to the first breastfeeding session. Overall, the mothers' oxytocin levels increased during the infants sucking and massage-like hand movements during feeding. Furthermore, mammalian studies have documented that maternal oxytocin is released in response to nipple stimulation, gaze and smell (Schaal, Coureaud, Doucet, Delaunay-El Allam, Moncomble, & Montigny, 2009).

Maternal touch is the predominant form of communication and affectionate maternal touch is a significant predictor of the quality of dyadic reciprocity (Ferber, Feldman & Makhoul, 2009). Maternal touch is of such importance to the infant that it can provide immediate soothing benefits for the infant in stressful environments. For instance, when maternal touch is added during the still-face procedure, infants show less reactive facial expressions in response to this previously-documented stressful paradigm (Herenstein & Campos, 2001). This provides overwhelming evidence that in the absence of facial and vocal emotional responsivity from their mothers, infants substitute maternal tactile proximity as a means for maternal availability compared with the classic still-face procedure which employs no tactile stimulation from the mother and where infants reliably exhibit enhanced distress. Maternal touch not only protects the infant from negative psychological stressors, but also negative physical experiences. Blass and Ciaramataro (1994) demonstrated maternal touch may stimulate the inhibition of neural pathways of pain responses during infant inoculations. The importance of touch extends the infant's psychological and physical realm, a predominant reason why researchers are interested in mother-infant touch patterns and dyadic communication in the presence of maternal depression.

3. Maternal depression affects mother-infant communication

Maternal depression affects the infant as well as the mother and the mother's depressive symptoms can contribute to a lack of nurturing behaviors and all forms of mother-infant communication are affected by maternal depression status (Jones et al., 1998; Lundy, Field, & Pickens, 1996). Without a means to efficiently communicate, the infant cannot effectively communicate emotions and needs to the mother. Infants of depressed mothers are less soothed by maternal touch and avert the gaze of their mothers more often than non-depressed mothers (Field et al., 2007; Boyd, Zayas, & McKee, 2006). The infant reactions to their depressed mother may in part be explained by maternal unavailability in the form of low amounts of nurturing touch (Jones, Gagnon, & Mize, 2006). As mother and infant's main form of communication is through touch, it may mean depressed mothers are less equipped to provide and appropriately respond to touch.

Depression also affects the mother's ability to process and respond to her infant's shifts in facial expressions (Murray and Cooper, 1997). As depressed mothers are less likely to provide soothing touch, less able to detect change in facial expressions, and are more likely to have trouble regulating their own emotions, infants of depressed mothers are at a high risk of atypical interactive communication patterns. Furthermore, impaired mother-infant communication is seen not only in clinically depressed mothers, but also mildly depressed mothers (Weinberg and Tronick, 1994) which implies that infants of mothers with depressive moods to clinically depressed mothers experience dysregulation in dyadic communication.

Infants of depressed mothers exhibited less interest expressions and more pre-cry expressions during a newborn imitation procedure (Lundy, Field, & Pickens, 1996). Infants of depressed mothers not only mimic facial expressions of their mother and exhibit behavioral depressive (on certain measures of the Brazelton, as defined by Lester and Tronick (1992)) symptoms, but the infants exhibit similar brain functioning patterns of their depressed mothers. Jones and colleagues (1998) found that the EEG patterns of the infants of depressed mothers showed greater relative right frontal EEG asymmetry and greater left frontal EEG power in comparison to the infants of non-depressed mothers. The frontal hemisphere asymmetry coupled with the lower left hemisphere activation is strikingly similar to the EEG patterns of depressed adults (Jones, Field, Fox, Lundy, & Davalos, 1997; Field, Fox, Pickens, & Nawrocki, 1995). Maternal depressive interactive styles inhibit the flow of optimal mother-infant communication.

Touch within the dyad has positive effects on infant emotional and cognitive development and can help decrease depressive symptoms in mothers. The present study will address outcome of infant brain plasticity and dyadic communication through patterns of affectionate dyadic touch. Several studies have addressed touch patterns in depressed and non-depressed dyads, however, the studies have not addressed the role of feeding status in outcomes of dyadic communication and infant brain development.

4. Role of breastfeeding as a buffer for impaired mother/infant communication in depressed dyads

Because of the benefits breastfeeding provides for infants, institutions such as the American Academy of Pediatrics (2005) recommend mothers breastfeed infants for 12 months. Infants who are breastfed have lower rates of obesity and more optimal developmental outcomes. Breast-fed infants also exhibit superior neurobehavioral profiles as early as one week (Hart, Boylan, Caroll, Musick, & Lampe, 2003). On measures of the Brazelton Neonatal Behavioral Assessment, breastfed infants performed superior to the formula-fed infants on measures of orientation, motor, range of state, and state regulation. Research focusing on healthy emotional development as a benefit of breastfeeding is of growing interest to researchers as recent studies suggest breastfeeding benefits extend beyond the realm of nutrition. Hart and her colleagues (2003) also found that breast-fed infants exhibited fewer sign of depression and withdrawal behaviors. The nutritional aspects, while important, may not completely convey the additional psychological benefits of breastfeeding. Rather, the act of breastfeeding itself lends the psychological benefits of breastfeeding. The percent of women who breastfed for their infant's first year of life was only 22.7% in the United States according to the CDC, however, mothers who suffer from depression are even less likely than their non-depressed peers to breastfeed (Field, 2008).

For breastfeeding mothers who suffer from depression, there is an understandable hesitation for taking antidepressants while feeding. Some mothers even cease breastfeeding in order to take antidepressants. It is usually because of a lack of knowledge about breastfeeding which leads the depressed mother to alternate methods of infant feeding (Jones, McFall, & Diego, 2004). Breastfeeding is a cheaper alternative to formula feeding; however, many women choose to formula feed as it permits the mother to have others feed her infant as well as to transition back to work in a relatively short amount of time. In addition, while government programs such as WIC promote breastfeeding, they also offer free formula supplementation when enrolled. The act of breastfeeding itself, however, may negate many depressive symptoms in the mother thus benefitting the infant as well.

Non-depressed mothers are not vulnerable to the same risks as depressed mothers. Communication in depressed mother-infant dyads differs greatly among feeding method (Feldman & Eidelman, 2003; Jones, McFall, & Diego, 2004). Due to the nipples of bottles expressing formula three times faster than breast milk, breast feeding typically takes longer than bottle feeding. The shorter duration of feeding times gives bottle feeding mothers less time to interact with their infants. Because depressed mothers interact with their infants less often than non-depressed mothers, within breastfeeding, depressed mothers are encouraged to interact with their infants for longer lengths of time than depressed/ bottle feeding mothers. Depressed mothers who breastfeed may garnish the benefits of mother-infant communication seen in non-depressed samples. The intimacy of breastfeeding coupled with its hormonal benefits may increase the quality of synchronous communication in the depressed mother and her infant. Depressed and bottle-feeding dyads, however, lack these advantages and the disrupted mother-infant remains asynchronous. Examining the feeding relationship in terms of maternal depression status and the impact of subsequent dyadic communication may indicate if breastfeeding serves to enhance mother-infant communication and infant neurodevelopmental patterns.

Purpose and Hypotheses

The purpose of this study is to examine developmental changes in the establishment of mother-infant communication within depressed and non-depressed dyads. Communication will be measured through the two most pervasive forms of mother-infant communication, touch and gaze. Because the study is concerned with mutual modes of implicit coordination through tactile communication, maternal vocalizations were not analyzed. Touch scales similar to those employed by Moszowski and Stack (2007) and Polan and Ward (1994) will be used to measure the quality of touch between mother and infant during play and feeding sessions. A variation of the Touch Scoring Instrument (Polan & Ward, 1994) will be used to measure maternal touch. The present study will divide one maternal touch scale into two separate touch scales, one measuring types of tactile behaviors and one measuring instrumental tactile behaviors. A variation of Infant Touch Scale (Moszkowski & Stack, 2007) will used, breaking the touch behaviors in two scales, one for types of touch and one for location of touch. Mother-infant communication during a feeding session, for the purposes of the present study, is defined as the percentage of time the infant affectionately touches the mother, the percentage of time the mother spends affectionately touching the infant, and the overall percentage of time during the visit in which the dyads engages in affectionate touch together.

Hypothesis 1:

Breastfeeding dyads are known to have higher levels of affectionate touch than bottle-feeding dyads (Lavelli & Poli, 1998) thus it is hypothesized that synchronous mother-infant communication will be facilitated by breastfeeding and provide the most benefits to depressed, breastfeeding mothers. It is expected that both depressed groups will show a lack of optimal touch at the 1 month visit. Specifically, at the 1-month, both depressed groups are expected to show a lower level of affectionate maternal touch and stimulating, instrumental (or active, matter-of-fact) touch as compared to both non-depressed groups based on a study conducted by Ferber (2004).

Hypothesis 2:

Breastfeeding has been shown to facilitate mother-infant interactions (Jones, McFall, & Diego, 2004). At 3-months, more affectionate touch will emerge within the depressed breastfeeding group, reflecting an emergence in the quality of mother-infant communication. Differences in percentages of optimal touch and gaze at the 3-month visit between the depressed bottle-feeding and depressed breastfeeding groups is expected because the breastfeeding groups will have had adequate time to garnish the benefits of breastfeeding interactions. The depressed breastfeeding dyads will display communication more similar to the non-depressed groups. It is also expected that only the breastfeeding depressed mothers will exhibit increased affectionate touch between the 1- and 3- month visits. An increase in gaze behaviors is predicted as well.

Hypothesis 3: While in previous studies breastfed infants demonstrate superior cognitive abilities in comparison to bottle fed infants (Tanaka, Kon, Okhawa, Yoshikawak, & Shimizu, 2009), non-depressed dyads should not show changes in their touch behaviors from 1 to 3 months as is expected for the depressed dyads because non-depressed dyads are not considered an at-risk population for desynchronization of dyadic communication, as are the depressed dyads. This expectation is supported by studies demonstrating impaired communication in depressed dyad (Field, Diego, & Hernandez-Reif, 2006; Hwa-Froelich, Loveland Cook, & Flick, 2008).

Hypothesis 4: The infants' EEG asymmetry scores are expected to follow typical patterns indicative of maternal mood status where infants of non-depressed mothers will be more likely to exhibit left frontal EEG activation and infants of depressed mothers will be more likely to exhibit right frontal EEG activation. The study will extend previous studies which use the EEG as a marker for infant temperament (Hane, Fox, Henderson, & Marshall, 2008; Jones, Field, & Almeida, 2009; Jones, McFall & Diego, 2004; Schmidt, Fox, Perez-Edgar & Hamer, 2009).

Hypothesis 5: In line with Greenough's model of neural plasticity (1987), this study will also attempt to demonstrate how experience-dependent plasticity can modify physiological predispositions for the expression of depressive symptoms. EEG data will be analyzed to determine if infant brain physiology differs as a function of maternal mood status and feeding as well as whether touch patterns mediate those differences.

We will also observe the role breastfeeding plays in the establishment of mother-infant touch patterns as it affects the physiology of infants of depressed and non-depressed mothers. It is believed that if touch patterns within the depressed dyads remain optimal from the 1- to 3-month visit then a shift in EEG hemispheric activation is expected at the 3-month visit. At the 3-month visit, the asymmetry patterns in the infants of depressed, breastfeeding mothers will be less likely to display left frontal hypoactivation, reflecting a more harmonious form of mother-infant communication established within the depressed breastfeeding dyads.

II.METHOD

Participants

Participants were recruited from local hospitals, lactation centers and birth announcement placed in the newspaper. The targeted demographic for the present study was primarily middle-class, adult women and their full-term infants. To determine eligibility for the study mothers were administered the Center for Epidemiological Studies Depression Scale (CES-D) during a telephone interview at 1-month. Only mothers considered depressed (scores of >16) and non-depressed (scores <12) as defined by the CES-D (Radloff, 1977) were asked to participate in the study.

113 mother-infant dyads participated in 1-month laboratory visit and 87 returned for the 3-month laboratory visit. The 1-month sample included 30 depressed mothers and 83 non-depressed mothers. The 3-month sample included 20 depressed mothers and 67 non-depressed mothers. The 1 –month data included 10 depressed, breastfeeding infants and their mothers; 10 depressed, bottle-feeding infants and their mothers; 49 non-depressed, breastfeeding infants and their mothers; and 21 non-depressed, bottle-feeding infants and 22 non-depressed bottle-feeding mothers. The 3 –month data included 8 depressed, breastfeeding infants and their mothers; 7 depressed, bottle-feeding infants and their mothers; 43 non-depressed breastfeeding infants and 47 non-depressed breastfeeding mothers; and 14 non-depressed bottle-feeding infants and

their mothers. Actual participant group number may be lower for certain analyses due to methodological issues.

The Center for Epidemiological Studies Depression Scale was used to prescreen participants for depression. The CES-D is 20 item questionnaire in which scores range from 0 to 60. A score of 12 or below is defined as "non-depressed" and a score of 16 or above is defined as "depressed." The CES-D has been shown to be a reliable questionnaire in terms of measuring depression (Radloff, 1977). In order to screen out mildly depressed mothers a second depression inventory, the Diagnostic Interview Schedule (Robins, Helzer, Croughan, & Ratcliff, 1981), was also administered.

Materials and Procedures

1 month visit

CES-D, BNBAS, IBQ, and DIS

Mothers and their infant came to the laboratory for the visit. Mothers signed consent forms, answered demographic questions, and completed the Infant Behavior Questionnaire (Rothbart, 1981) and the Center for Epidemiological Studies Depression Scale. The IBQ demonstrates good reliability and is applicable to neonates as early as 2 weeks (Worobey and Blajda, 1989). In the case of a depression diagnosis on the CES-D, mothers were also asked to complete the Diagnostic Interview Schedule. While mothers were completing the questionnaires, a research assistant administered the Brazelton Neonatal Behavioral Assessment Scale (Brazelton & Nugent, 1995). All research assistants who administered the Brazelton were trained to .90 reliability. The

Brazelton assessment could not be completed on seven of the infants. After the Brazelton was completed a baseline EEG was taken while the infant sat in the mother's lap or in an infant seat. The EEG recording was taken for approximately 5-6 minutes while the infant was in a quiet and alert state. Five infants (3 at 1 month and 2 at 3 months) could not endure wearing the cap for the full 5 minutes and 9 other infants (5 at 1 month and 4 at 3 months) had unusable EEG data.

Feeding Session

After an initial play interaction mothers were asked to feed their infants. The feeding session lasted as long as it took the mother to feed her infant. Once the mothers began the feeding session, they were left alone to breastfeed or formula feed their infant. Both mother and infant were taped during the entire feeding session was taped, however only the first five minutes of the feeding session were used for behavioral coding analyses. The coding system utilized a second-by-second coding basis. The feeding session coding system measured both mother and infant behaviors. Kappa scores ranged from .78 to .95. Reliability scores for each coding scale are reported in Tables 1 through 4.

Because of the interest in touch behaviors of mother and infant, additional more comprehensive touch scales were employed. A variation of the Infant Touch Scale, developed by Moszkowski and Stack (2007) will be used to code infant touch behaviors. To be classified as infant touch, the infant had to actively initiate or reciprocate touch with the mother. Seven types of infant touch are used in the Infant Touch Scale as follows: static, stroke, grab, finger, mouth, pat, and pull (as shown in Table 1). The 7 locations used to code infant touch were as follows: face, mouth, hand, trunk, feet, mother, and clothes (as shown in Table 2). In a study by Ferber, Feldman, and Makhoul (2007) three broad touch categories encompassed the types and locations of touch in the Infant Touch Scale, soothing/regulatory, reactive, and passive. (Soothing- stroke, finger, mouth; reactive- grab, pat, and pull; passive- static). Touch was examined by grouping touch in three categories: self, mother, and other (defined as a location the infant touches other than the mother or self). The current study utilized a modified version of the Touch Scoring Instrument (1994) used by Polan and Ward to classify maternal touch patterns (as shown in Table 3). In this coding system, touching behaviors are scored on a second-by-second basis on 7 categories of touch. The 7 categories are as follows: 7-firm touch- firm patting, stroking, massaging with the whole hand; 6-light active touch- affectionate kissing, caressing, or stroking; 5-passive touch- passive contact, resting the hand in contact with the infant, comforting presence for infant without interrupting flow of attention, has been shown as a component of the affectionate composite 4-not affectionate/passive/reactive- any form of maternal touch which does not fall into the affectionate, passive, or reactive touch categories; 3-no touch; 2-awkward holding- holding the child in an uncomfortable manner with an uninterested or neglectful attitude; 1-rough handling- exercising forceful or abrupt restraint or physical control of the child with an angry or punitive quality.

A maternal active touch scale was utilized as well (as shown in Table 4). The maternal active touch scale utilized 5 forms of maternal active touch as follows: 5-

vestibular stimulation- movements that change the infant's orientation in space; repositioning, swaying, rocking, lifting; 4-matter-of-fact touch- purposeful utilitarian contact; ex. wiping the child's mouth eye; moving infant's hand if interfering with feeding; 3-proprioceptive stimulation- flexion and extension of the infant's limbs, often used during dressing; 2 - no active touch- No active maternal touch present, but the mother still touches the infant; 1- no touch- The mother is not in contact with the infant. A 3 item gaze scale was used as well. Table 5 defines the 3 codes as follows: 3 – infant gazes at mother, 2 –infant gazes elsewhere, 1 –infant is sleeping, infant has eyes closed.

Physiological Recordings

A stretch lycra cap (Electro Cap, Inc.) with the international 10-20 system was used to measure the EEG recordings. Omni prep abrasive gel and electrode gel was placed in the 8 electrode sites measured. Impedances were brought below 5K ohms or the sites were re-abraded. The sites utilized were as follows mid frontal (F3 and F4), central (C3 and C4), parietal (P3 and P4) and occipital (O1 and O2). All 8 sites were referenced to the vertex (Cz). The vertex was used as a site of reference as previous infant EEG research almost exclusively utilizes Cz as the site of reference. Using Cz as our site of reference allowed our results to be easily compared to other infant EEG research. EOG was also obtained to easily remove eye movement artifacts from the EEG data. Two mini electrodes were placed on the infant's face, one on the outer canthus and the other on the supra orbit position. The EEG electrical signal was amplified using SA Instrumentation Bioamps and bandpassed from 1-100 Hz. The EEG activity from each lead was streamed onto a computer screen. The EEG sampling rate on-line rate was 512 samples per second.

The EEG recordings were saved to a computer hard drive using Snapstream v. 3.21 (HEM Data Corp, 1991).

Although there is no universally accepted criterion for frequency bands used for infants, typically the 3-6 Hz frequency bands are used for young infants and the 6-9 Hz range is used for older infants (Cuevas & Bell, 2010; Jones, Field, Fox, Lundy, & Davalos, 1997). Thus, this study analyzed the 3-6 Hz range at 1-month and 6-9 Hz range at 3-months. The data will also be looked at using each individual frequency bins so spectral trends can be noted. The EEG data are scored for artifacts from eye and motor movements. To obtain asymmetry scores across 1- and 3-month recordings all recordings were normalized using a natural log transformation and asymmetry scores were computed (ln(right)- ln(left)) so that negative scores reflect relative right hemispheric activity and positive scores reflect relative left hemispheric activity.

3 month visit

Procedures of the 3 month visit were identical to the 1 month visit.

III.RESULTS

Statistical Methods

The mother-infant dyads were assigned to four different groups: the depressed, breastfeeding group; the non-depressed, breastfeeding group; the depressed, bottle-feeding group; and the non-depressed bottle-feeding group. The mothers assigned to one of the depressed groups scored above 16 on the CES-D. Assignment of the feeding groups was dependent on mother-reported feeding practices. Mothers in the breastfeeding group were breastfed exclusively and no formula was given to the infant at the 1 – or 3 – month visit. Mothers who bottle fed exclusively or supplemented breast milk with formula were assigned to the bottle-feeding group. Because maternal and infant tactile behaviors have been demonstrated to cluster in three specific forms of touch: affectionate (stroke, finger categories of touch), reactive (grab, pull, pat categories of touch), and passive (static touch) (Ferber, Feldman, & Makhoul, 2007) the present study combined touch categories in these three forms for data analysis. The composite scores for touch categories weighted individual forms of touch, with the most optimal touch receiving the highest weight and weighting the other touch categories in descending order of optimality. All analyses considered significant are $p<.05$ unless otherwise noted.

Hypothesis 1: *Depressed dyads will show a lack of optimal touch at the 1 month visit.*

Maternal Tactile Behaviors

At the 1-month visit, it was predicted that the depressed mothers would show less affectionate touch than the non-depressed mothers. Interestingly, the differences in affectionate touch existed between the non-depressed feeding groups.

Analyses comparing two types of maternal affectionate touch, deep affectionate touch and light affectionate touch, separately yielded no significant results between the four groups (depressed, breastfeeding mothers, depressed, bottle feeding mothers, non-depressed breastfeeding mothers, and non-depressed bottle feeding mothers) Therefore, maternal deep affectionate touch and maternal light affectionate touch were combined into a single weighted variable, assigning deep affectionate touch a higher weight than light active touch. A one-way ANOVA revealed a significant effect for group (depressed, breastfeeding; depressed, bottle-feeding; non-depressed breastfeeding; non-depressed bottle-feeding) in the amount of maternal affectionate touch present at the 1 month visit, $F(3, 87) = 6.25$, $p < .05$. Post hoc comparisons using Tukey HSD indicated the non-depressed breastfeeding mothers engaged in significantly more affectionate tactile behaviors than the non-depressed and depressed bottle-feeding mothers. The difference in maternal affectionate touch behaviors between the non-depressed breastfeeding group and the depressed breastfeeding group approached significance ($p = .069$). However, the percentage of maternal affectionate touch of both breastfeeding groups (*M* non-depressed, breast = 13.60, *SD* = 8.42; *M* depressed, breast = 15.12, *SD* = 13.44) were higher than both bottle-feeding groups (*M* non-depressed bottle = 3.89, *SD* = 12.24; *M* depressed, bottle = 5.54, *SD = 12.02*).

Zero to low percentages of maternal reactive touch were coded at both the 1- and 3- month visits, therefore a composite score was created to reflect suboptimal maternal tactile behaviors. The composite variable included rough handling, awkward handling, and no touch. The behaviors were weighted, assigning the highest weighted average to rough handling. At the 1 month visit, mothers in the four groups did not display significant differences in suboptimal tactile behaviors.

It was also hypothesized that the depressed mothers would show less instrumental, or matter-of-fact, touch than the other groups. However, differences in utilitarian touch did not exist between the four groups of depressed and non-depressed breast- and bottle-feeding mothers. A one-way ANOVA confirmed that no significant differences existed at the 1 month visit between the non-depressed and depressed breast- and bottle-feeding mothers.

A one-way ANOVA was conducted to investigate differences in frequency of instrumental touch provided by the two feeding groups during the 3 month visit. Similar to the analysis of utilitarian touch at the 1 month visit, the ANOVA revealed no significant differences.

Infant Tactile Behavior

In the present analyses, infant tactile behaviors included three forms of touch. Reactive touch included patting, pulling and grabbing. Static touch was defined as passive touch. Lastly, affectionate touch was defined as light of deep affectionate touch. Forms of affectionate touch are considered the most optimal patterns on infant tactile behaviors.

Infant reactive touch did not differ between the groups at the 1- or 3- month visit. To determine if infant reactive touch differed between groups across age, a composite variable was created by combining infant reactive tactile behaviors at 1 and 3 months of age. A one-way ANOVA comparing the effect of depression/feeding status on reactive tactile behaviors revealed no significant effects.

To determine whether the reactive touch categories at the 1 – and 3 –month visit were more reflective of infant active touch rather than suboptimal tactile behaviors, a composite score was created for infant active touch. The composite score included patting, pulling, and stroking, all of which have been demonstrated as indicative of infant active tactile behaviors (Moszkowski, Stack, Girouard, Field, Hernandez-Reif, & Diego, 2009). However, a one-way ANOVA did not yield any significant differences in infant active touch between the groups at the 1 or 3 month visit.

Infants could have displayed an absence of touch altogether rather than utilizing suboptimal touch patterns, therefore a one-way ANOVA comparing occurrence of no touch between the four groups was conducted. The ANOVA was significant indicating the groups differed in the amount of time spent engaging in no tactile behaviors, $F(3,68) = 2.95$, $p < .05$. The infants of depressed, breastfeeding mothers engaged in more tactile behaviors than the non-depressed breastfeeding group at the 1 month visit. The same pattern was revealed in a post hoc comparison of the two breastfeeding groups at the 3 month visit, as shown in Figure 1.

High occurrences of infant self-touch are an indication of maternal unavailability. Therefore, percentage of infant self-touch during the feeding sessions was compared between the groups. Infant self-touch was coded from the Infant Touch Location scale (Table 2) as the amount of time the infant spent touching: body, mouth, or face/head/shoulder/neck. At 1 month of age significant differences in infant self-tactile behaviors were present, $F(3,81) = 2.76$, $p < .05$. Post hoc comparisons using the Tukey

HSD revealed that only the non-depressed breast- and bottle-feeding groups differed significantly in the amount of infant self-tactile behavior. The non-depressed, bottle fed infants engaged in significantly more self touch behaviors than the non-depressed breastfed infants.

At the 3 month visit, infants in the four groups differed in amount of self touch as indicated by a one-way ANOVA comparing the amount of infant self touch between the four groups, $F(3,70) = 11.32$, $p < .05$. Post hoc comparisons using the Tukey HSD revealed that both groups of bottle fed infants displayed significantly more self-tactile behaviors than the breastfed infants groups. These findings indicate that at the 3 month visit the infants of depressed, breastfeeding mothers had lower self-tactile behaviors compared to the 1 month visit. The same trend was not evident in the bottle feeding groups as shown in Figure 2.

Infant Gaze Behaviors

It was expected that infants of depressed mothers would gaze at their mothers less often than the infants of non-depressed mothers. One month old infant groups did not differ in the amount of time spent gazing at mother. However, a significant effect for infant group was found for the amount of time the infant spent gazing away from their mothers, $F(3,81) = 2.78$, $p < .05$. Post hoc comparisons using the Tukey HSD revealed the non-depressed breastfed infants spent longer amounts of time gazing away from the mother. This finding suggests typical development in breastfeeding dyads. Breastfed infants show superior neurobehavioral profiles in comparison to bottle-fed infants (Hart, Boylan, Carroll, Musick, & Lampe, 2003), thus the breastfeeding infants gazing away from their mothers may be indicative of exploratory behaviors when exposed to a novel environment (a laboratory setting). No significant differences were found at the 3 month visit for gaze behaviors.

Dyadic Communication

The prior analyses assessed mother and infant tactile communication separately. Further analyses of tactile behaviors combined occurrences of maternal and infant patterns. A one-way ANOVA comparing dyadic affectionate tactile behaviors at one month differed significantly between the four groups, $F(3, 82) = 4.98$, $p < .05$. Post hoc comparisons using Tukey HSD indicated the non-depressed breastfeeding dyads engaged in significantly more affectionate tactile behaviors than the non-depressed breastfeeding dyads. These findings indicate that at 1 month, the breastfeeding mother-infant dyads communicate with affectionate touch more frequently than bottle feeding dyads. The depressed groups did not differ from each other at 1 month.

To determine if the groups differed in the amount of affectionate touch provided within the dyad across age, a composite variable combining mother and infant affectionate tactile behaviors at the 1- and 3- month visit was created. A one-way ANOVA comparing differences of dyadic affectionate tactile behaviors between groups revealed a significant effect, $F(3,50) = 9.25$, $p < .05$. Post hoc comparisons using Tukey HSD indicated the non-depressed breastfeeding dyads engaged in significantly more affectionate tactile behaviors than the depressed and non-depressed bottle-feeding groups. Similarly, the depressed, breastfeeding groups engaged in more affectionate tactile behaviors than the non-depressed, bottle-feeding group. The difference in affectionate dyadic tactile behaviors between the depressed groups was significant, $p = .05$. The depressed, breastfeeding dyads engaged in significantly more affectionate tactile behaviors than the depressed, bottle-feeding dyads.

Combined Age Tactile Behaviors

Collapsing the infant affectionate tactile behaviors across age and entering the composite variable into a one-way ANOVA yielded a significant effect, $F(3,55) = 5.29$, $p < .05$. Post hoc comparisons revealed the infants of depressed breastfeeding mothers provided more affectionate touch than the infants of non-depressed bottle-fed infants. The non-depressed groups also differed significantly by feeding method, with the breastfed infants engaging in more affectionate touch with their mothers than the bottle-fed infants.

Hypothesis 2: *Affectionate touch patterns will increase from the 1 – to 3 – month visit in the depressed breastfeeding group in comparison to the depressed, bottle-feeding group.*

Maternal Tactile Behaviors

Differences in maternal affectionate touch between groups at the 3 month visit reached significance, $F(3,72) = 2.72$, $p = .05$. Post hoc comparisons using Tukey HSD suggested a trend ($p = .084$) for the non-depressed breastfeeding mothers providing more affectionate touch to their infants than the depressed bottle-feeding group as shown in Figure 3.

Because the 3 month visit yielded no significant effect when analyzed alone, the maternal affectionate tactile behaviors were combined into one variable across age. Mothers who did not participate in both lab visits were excluded from the present analysis. The composite variable yielded a significant effect, $F(3,57) = 5.52$, $p < .05$. Post hoc comparisons using Tukey HSD suggested that the non-depressed breastfeeding mothers engaged in more affectionate tactile behaviors than the non-depressed and depressed bottle-feeding groups. These results suggest that bottle-feeding mothers provide less affectionate touch to their infants regardless of depression status and infant age.

Infant Tactile Behaviors

A composite score was created to examine the infants' affectionate touch behaviors toward the mother at the 1 month visit. The composite variable consisted of stroking, fingering, and passive touch. The tactile behaviors were weighted, assigning the highest weight to stroking. The composite variable was entered in a one-way ANOVA, which indicated that the breastfed infants engaged in more affectionate touch with their mothers than the bottle fed infants, $F(1,88) = 8.73$, $p < .05$.

A one-way ANOVA revealed significant differences in infant affectionate touch between the groups for the 3 month visit, $F(3,69) = 3.22$, $p < .05$. Post hoc comparisons using the Tukey HSD revealed the non-depressed breastfeeding mothers were affectionately touched by their infants significantly more than the non-depressed, bottle-feeding group.

A one-way ANOVA revealed a significant effect for infant group on the percentage of time spent touching mother at the 3 month visit $F(3,70) = 9.69$, $p < .05$. Post hoc comparisons using the Tukey HSD indicated that the depressed, breastfed infants touched their mothers significantly more than the depressed and non-depressed bottle-feeding groups. Similarly, the non-depressed breastfed infants touched their mothers significantly more than both bottle feeding groups. Taken together, these findings suggest that infant tactile behaviors directed toward the mother increase across age and between feeding methods. This pattern may be due to the fact that at the 1 month visit dyadic communication has not fallen into a stable pattern of behavior.

Dyadic Communication

Differences in affectionate touch within the dyad persisted across age. A one-way ANOVA revealed a significant effect for dyadic affectionate tactile behaviors between groups, $F(3, 68) = 7.15$, $p < .05$. Similar to the 1 month visit, post hoc comparisons using Tukey HSD revealed differences between the non-depressed breastfeeding group and the depressed and non-depressed bottle-feeding groups. Non-depressed breastfeeding dyads engaged in significantly more mutual affectionate tactile behaviors than the depressed and non-depressed bottle feeding dyads. Taken together, these results indicate that the affectionate tactile behaviors in the depressed bottle-feeding dyads decreased as age increased. Depressive symptoms of the bottle feeding mother create a template from which the infant patterns his or her touch behaviors.

Hypothesis 3: *Differences in tactile behaviors between feeding method should be more pronounced in the depressed dyads than the non-depressed dyads.*

Counter to the hypothesis, the only groups differing in tactile behaviors at the 1 month visit included only the non-depressed feeding groups.

At the 3 month visit, a one-way ANOVA comparing maternal suboptimal touch between the groups revealed a significant effect, $F(3,72) = 4.69$, $p < .05$. Post hoc comparisons using the Tukey HSD revealed the non-depressed breastfeeding mothers engaged in significantly less suboptimal behaviors than the non-depressed bottle-feeding mothers.

A one-way ANOVA comparing maternal passive touch revealed a significant effect for group, $F(3,72) = 3.89$, $p < .05$. The non-depressed bottle-feeding mothers engaged in significantly more passive touch than the non-depressed breastfeeding mothers. No significant differences were found between groups at the 1 month visit.

At the 1 month visit, the mother groups did not differ in the amount of tactile stimulation provided to the infant. However, a one-way ANOVA comparing the absence of maternal tactile behaviors at the 3 month visit revealed a significant effect for group, $F(3,72) = 4.69$, $p < .05$. The non-depressed bottle-feeding mothers spent significantly less time engaging in tactile behaviors than the non-depressed breastfeeding groups.

Hypothesis 4: ***At 1 month, the infant EEG scores will follow patterns typically indicative of maternal mood status.***

EEG Analysis

A two-way repeated measures ANOVA, conducted using the 3-6 Hz alpha frequency band, revealed no significant differences in EEG activity between the four groups at 1 month of age. The 3-6 Hz range has been identified as the equivalent of the adult alpha band in 1 month infants and the 6-9 Hz range for older infants (Jones, McFall, & Diego, 2004). However, the 6-9 Hz band was still analyzed for the 1 –month EEG data to determine if differences existed. An analysis was conducted using the 6-9 Hz alpha frequency band found no significant differences in EEG asymmetry scores. At the one month visit no differences in EEG activity and asymmetry scores existed between the infant groups. The depressed, breastfeeding group displayed slight right frontal EEG asymmetry, however the infants of depressed, bottle-feeding mothers did not. The infants of non-depressed, bottle-feeding mothers also displayed right frontal EEG asymmetry.

The infants of non-depressed breastfeeding mothers displayed greater left frontal EEG asymmetry.

A two-way repeated measures ANOVA comparing EEG activity between the four groups at 3 months of age revealed no significant differences in overall measured EEG activity. To investigate the presence of region-specific differences, further analyses conducted compared frontal EEG activity.

Differences in EEG asymmetry scores among the infants remained present when the analysis utilized the 6-9 Hz band at both age groups. A two-way repeated measures ANOVA comparing infant EEG asymmetry scores between groups at both 1- and 3-months revealed a significant effect for group at the 3-month visit, $F(1, 67) = 4.47$, $p < .05$. As expected, the infants of depressed, bottle-feeding mothers were among the only infants to display an overall right frontal EEG asymmetry score.

Hypothesis 5: ***Infants of depressed breastfeeding dyads will display a shift in hemispheric activation from the 1 – to 3 –month visit***

A two-way repeated measures ANOVA revealed significant differences within the infant groups indicating that frontal EEG asymmetry scores significantly differed from the 1- to 3-month visit, $F(1,67) = 5.71$, $p < .05$. As expected, only the infants of the depressed, bottle-feeding mothers exhibited a pattern of right frontal EEG asymmetry at 3 months of age. Interestingly, this group of infants displayed greater left asymmetry at the 1-month visit, the only infant group to display this pattern at 1 month of age. A more typical EEG pattern would display a right to left EEG asymmetry shift as a function of age, reflecting cortical maturation (Zhu et al., 2010).

To examine hemispheric differences of the four groups at the 3-month visit a Group (depressed, bottle feeding; non-depressed, bottle-feeding; depressed breastfeeding, non-depressed breastfeeding) x Region (frontal, central, partietal, occipital) x Hemisphere (left versus right) repeated measures ANOVA was conducted using EEG power as the dependent variable. The analysis yielded a significant interaction effect for Region x Hemisphere, $F(3,67) = 4.35$, $p <.05$. Further ANOVAs compared regions separately, focusing on hemispheric differences in EEG power the frontal lobes. EEG power is reciprocal to activation, so that higher power reflects less activation of a brain region. A Group x Hemisphere repeated measures ANOVA revealed a significant Group x Hemisphere interaction, $F(3,76) = 3.46$, $p < .05$ for the frontal region. Post-hoc comparisons revealed no significant differences between the groups, however, the infants of depressed, bottle-feeding mothers and the infants of non-depressed breastfeeding mothers showed the least amount of left hemispheric activity(*M* depressed, breastfeeding = 1.97, *SD* = 1.52; *M* depressed bottle-feeding = 2.23, *SD* = .76; *M* non-depressed breastfeeding = 2.45, *SD* = .93; *M* non-depressed bottle-feeding = 1.92, *SD* = 3.32). The depressed bottle-feeding group also showed the highest amount of right frontal hemispheric activity (*M* depressed, breastfeeding = 2.55, *SD* = .66; *M* depressed bottle-feeding = 2.04, *SD* = 1.18; *M* non-depressed breastfeeding = 2.42, *SD* = .94; *M* non-depressed bottle-feeding = 2.52, *SD* = 2.82).

Predicting Infant Behavior

A multiple regression analysis was conducted to determine the predictability of the average time infants spent touching their mothers at 3 months using 3 month EEG asymmetry scores, mother depression status, feeding status, and the amount of time the infant spend touching the mother at 1 month, as the predictors. Due to a loss of participants between the 1- and 3-month visits, the regression utilized mean substitution for the missing participants. The regression was significant, $F(4, 108) = 4.18$, $p = .003$. The predictors are significant contributors to the model of 3 month infant tactile behavior provided to the mother. The sample multiple correlation coefficient equaled .37, indicating that 13% of the variance could be accounted for by the multiple regression equation. Among the individual predictors the bivariate correlations for 3-month EEG asymmetry scores and feeding status were significant, ($p < .05$). The relative importance of the individual predictors to the overall model is difficult to determine, as feeding status is significantly correlated to EEG asymmetry scores and the infant tactile behaviors provided to the mother at 1 month.

IV.DISCUSSION

Overview of Results

Differences across the four groups (breastfeeding non-depressed, breastfeeding depressed, bottle-feeding non-depressed and bottle-feeding depressed) existed at both age groups. At 1 month, the primary differences in tactile behaviors existed between the non-depressed groups for both infants and mothers. The differences persisted through the 3 month visit; however, especially for the depressed bottle-feeding group which showed a greater proportion of suboptimal tactile behaviors. The depressed-bottle feeding dyads were the only group to exhibit a significant decrease in overall positive dyadic communication. Similarly, only the infants of depressed bottle-feeding mothers displayed a left to right frontal EEG asymmetry shift from the 1- to 3-month visit. The plasticity of the infant brain seems to be especially vulnerable to environmental interactions in the presence of maternal depression. Specifically, it worked as a disadvantage for the depressed bottle-feeding group as exhibited by the EEG shift across age. As expected depressive symptoms of the mother most impacted the depressed bottle-feeding dyads.

Touch patterns in depressed and non-depressed breast- and bottle-feeding dyads

It was hypothesized that mother-infant communication would provide the most benefits to depressed, breastfeeding dyads as reflected in behavioral measures and infant EEG patterns. At the 1 month visit, depressed groups did not display statistically significant differences in their tactile behaviors. However, counter to the hypotheses that at the 1 month visit the depressed feedings groups would display similar tactile behaviors, the depressed breastfeeding groups were, on average, more similar in behavior to the non-depressed breastfeeding dyads at both the 1- and 3-month visits. On combined age measures of infant affectionate touch, infants of depressed mothers displayed higher levels of optimal tactile behaviors. This finding was unexpected, however, the trend has been replicated in other studies (Beebe et al., 2008). The EEG hypotheses were partially supported by the data and are consistent with previous studies (Field, Fox, Pickens, and Nawrocki, 1995; Henriques & Davidson, 1990; Jones, Field, Fox, Lundy, & Davalos, 1997). Overall, the data support the transactional model of brain plasticity whereby genetic predispositions, in the present study we refer to depression, are determinants of the susceptibility to environmental interactions, both positive and negative.

Interestingly, the depressed, breastfeeding group never displayed levels of touch comparable to the infants of depressed, bottle-feeding mothers as was hypothesized. Rather, the depressed, breastfeeding group exhibited tactile behaviors more similar to those of the non-depressed breastfeeding group even at the 1 month visit. The depressed bottle-feeding group was the only group to exhibit statistically significant increases in suboptimal touch behaviors and decreases in mother-infant communication across age. Taken together, these findings suggest that the depressed, breastfeeding dyads were not affected by the depression status of the mother in the same way as the depressed, bottle-feeding group. Theoretical explanations for the findings include perception-action accounts, the influence of brain plasticity upon infant emotional development, and genetic-environmental-hormonal interactions.

Role of tactile behaviors in mother-infant communication

Passive touch is viewed as a static form of affectionate touch which the mother may utilize to prevent interrupting the infant's flow of attention (Polan & Ward, 1994). Although all four groups of mothers utilized passive touch, the non-depressed bottle feeding group utilized this form of touch significantly more than the other groups. The finding may represent the bottle-feeding mothers' attempt to interact with the infant during feeding; it is harder for a bottle-feeding mother to touch her infant during feeding than a breastfeeding mother who does not need to hold a bottle. The mother may also be attempting to initiate touch through skin-to-skin contact, an important mechanism to facilitate affectionate touch within the dyad (Feldman, Weller, Eidelman, & Sirota, 2003). Taken together, the findings that non-depressed bottle-feeding mothers engaged in more passive touch than the non-depressed breastfeeding mothers and because the bottle-fed infants of non-depressed mothers did not show greater relative right asymmetry, along with previous findings, may implicate passive touch as a marker for maternal attempts to initiate and maintain communication with her infant.

Another interesting finding was the occurrence of infant self-touch behaviors. Previous studies have shown that infant self-touch is utilized as an infant self-soothing behavior (Moszkowski, Stack, Girouard, Field, Hernandez-Reif, & Diego, 2009). The finding that bottle-fed infants touched their own-selves more than the breastfed indicates that the bottle-fed infants engaged in more self-soothing behaviors than the other infants. The depressed, breastfeeding infants lowered the amount of self-touch from 1- to 3-months, whereas the depressed, bottle feeding group increased self-touch behaviors. A moderate amount of infant self-soothing behaviors is considered healthy and has been linked to self-regulation (Moszkowski & Stack, 2007). However, utilizing self-soothing behaviors, such as self-touch, too often may signal a lack of soothing behaviors provided to the infant by the mother. Depressed mothers often lack the capability to properly assess their infants' needs. A lack of proper emotional processing has been demonstrated to affect the perception of other's emotions. Similarly, it is more difficult to detect microscopic shifts in the exhibition of facial emotions. These findings mimic behaviors in people exhibiting depressive symptoms. Infants provide themselves with the touch their mother does not offer. Dyads that do not interact appropriately may experience a de-synchronization in communication. Thus, future studies may examine infant self-touch as a marker for asynchrony in mother-infant communication.

EEG patterns in infants of depressed and non-depressed breast- and bottle-feeding groups and the role of tactile behaviors in brain development

An explanation for the lack of appropriate mother-infant communication of the depressed, bottle-feeding dyads focuses on infant brain plasticity. Similar to their tactile behavior changes, the infants of depressed, bottle-feeding mothers displayed an atypical EEG shift from the 1- to 3-month visit. The typical developmental trajectory, as measured by the EEG, is marked by right frontal asymmetry shortly after birth. This pattern is thought to reflect an immature left frontal lobe. The right frontal lobe is associated with withdrawal behaviors which also encompass more primitive emotions associated with the flight response of behavior, such as fear and disgust. As the brain develops, the left frontal lobe matures and higher-order approach emotions such as happiness and anger become more pronounced in the infant. This finding has been demonstrated both behaviorally and physiologically (Blanton, Levitt, Thompson, Narr, Capetillo-Cunliffe, & Nobel, 2001; Lavelli & Fogel, 2005). The infants of the depressed, bottle-feeding mothers, however, did not display a typical right to left shift in frontal EEG patterns. Instead, these infants displayed a left to right shift from the 1 to 3 month visit. Previous studies have also demonstrated that people prone to depressive symptoms typically display right frontal EEG asymmetry (Thibodeau, Jorgensen, & Kim, 2006). The present study demonstrates that the right frontal asymmetry in EEG patterns is apparent in bottle feeding infants whose mothers are depressed as early as 3 months of age.

Hemispheric differences in EEG patterns were apparent among the 4 groups of mother-infant dyads. The breastfed infants showed greater activity in the left hemisphere at 3 months of age. It is known that no formula completely provides the extent of nutrients provided by natural breast milk (American Academy of Pediatrics, 2005). Therefore, breastfed infants may be at an early advantage of the formula fed infants in terms of brain development. Greater activity in the left hemisphere in infants reflects greater brain maturation in the left hemisphere than the infants who display less left hemispheric activity. A recent study by Zhu et al.(2011) studying EEG patterns across aging found a pattern in children aged 0-10 years in which a right to left hemispheric interaction increased with age and left to right hemispheric interactions decreased with age. The present study demonstrated that infants who are bottle-fed and born to depressed mothers are more likely to display atypical EEG patterns of brain development and also more likely to exhibit EEG patterns indicative of withdrawn interactive styles at 3 months of age.

Maternal depression and feeding status in relation to touch patterns: Breastfeeding may temper the effects of maternal depression on the infant

Mothers who breastfeed have higher levels of the neuropeptide oxytocin (Zinaman, Hughes, Queenan, Labobok, & Albertson, 1992). Oxytocin is released in mammals and humans in response to tactile stimulation and lactation. Oxytocin is thought to not only promote maternal behaviors in mammals and humans but also decrease irritable and depressive symptoms displayed by the mother (Carter, 1998). Furthermore, oxytocin also promotes bonding of the mother-infant dyad. This finding accounts for the study's finding that breastfeeding dyads displayed higher levels of quality mother-infant communication. Bottle-feeding dyads are not expected to have levels of oxytocin comparable to breastfeeding mothers. Thus, the depressed, bottle-feeding dyads are the least likely to benefit from the oxytocinergic bonding pathway, and quite arguably, are the dyads which could benefit the most from it as well. Recent studies on oxytocin have also linked the neuropeptide to the development of social interaction skills (Andari, Duhamel, Zalla, Herbrecht, Leboyer, & Sirigu, 2010). The results of the touch study are in accordance with previous oxytocin studies (Nissen, Lilja, Widstrom,& Uvnas-Moberg, 1995). Future studies measuring mother-infant touch patterns in accordance with oxytocin samples will provide researchers a direct link between mother-infant communication and oxytocin levels. Low levels of oxytocin may not only impede the development of maternal behaviors and bonding of the dyad, but may also interfere with the development of the infant's social skills, further perpetuating the asynchrony of communication within the depressed, bottle-feeding mother-infant dyad.

Genetic, environment, and hormonal influences impact communication within the dyad

The hypothesis that brain plasticity is not only experience-expectant, but also experience-dependent was confirmed. The infants of depressed, bottle-feeding mothers displayed EEG patterns consistent with withdrawal behavior and showed lower quality of mother-infant communication. Synthesizing explanations for the EEG asymmetry patterns displayed in the infants of depressed, bottle-feeding mothers but not the infants of depressed, breastfeeding mothers creates a fit for the transactional model of brain plasticity (Fox, Calkins, & Bell, 1994). The transactional model of brain plasticity proposes an interaction of genetics and environment as determining the progression of infant brain development. Infants born to depressed mothers are at a higher risk of developing depressive symptoms due in part to genetic influences. However, environmental influences enhance or inhibit the expression of genetic dispositions. Asynchrony of mother-infant communication coupled with a genetic predisposition for depression expresses depressive symptoms in the infant both behaviorally and physiologically. The transactional model of brain plasticity is consistent with the findings of the present study and accounts for the EEG differences between the two depressed groups.

The effect of hormonal influences cannot be overlooked when examining environmental influences on infant brain development and behavior. Infants of depressed mothers are exposed to more cortisol and norepinephrine, hormones excreted in response to stress. Infants exposed to high levels of these hormones in utero are more likely to have high levels of these hormones themselves, low levels of dopamine and serotonin, and to also demonstrate suboptimal neurobehavioral profiles (Field & Diego, 2008; Lundy et al., 1999). Assuming over-exposure to stress hormones in utero is detrimental to the infant, this may account for the differences in mother-infant communication between the depressed dyads.

Socio-environmental contexts enhance predisposition to express depressive symptoms.

Action within the dyad may drive- or further cement- affective states, and an environment in which the mother is prone to depression may establish a cyclical "depressive" style of interaction between the mother and infant, both influencing self and the other. Mother-infant tactile behaviors are usually viewed upon as external displays of internal states. Without denying this point, it is also possible that the tactile behaviors of the dyad drive internal states as well. Differences in tactile behaviors among the non-depressed groups may be explained in terms of these studies. Out of necessity, a breastfeeding mother holds her infant closer to her body to feed than mothers who bottle-feed. Because researchers such as Cacioppo and colleagues (1993) conducted a study which supports the notion that extension of the arm is associated with disgust/withdrawal affect and flexion is associated with approach emotions (1993), it may be that the mother's postural position influences her affective states while feeding her infant. This idea would be consistent with the findings of Feldman et al. (2004) which demonstrated mothers positioned their failure to thrive infants out of arms' reach.

Infants of depressed mothers are also developmentally affected by lack of touch. Silberstein and colleagues (2009) noted mothers who defined their infants as "problematic" during breastfeeding sessions touched their infants less frequently and the infants touched their mothers more forcefully. Infants of mothers who provide little touch are more likely to avoid touching their mothers (Feldman, Keren, Gross-Rozval, & Tyano, 2004). Tactile stimulation not only helps the infant to discover self, but also encourages haptic exploration. The desire to mouth and touch objects allows infants to acquire and refine motor skills (Needham, Barrett, & Peterman, 2002).Therefore, infants of depressed mothers who engage in low amounts of touch may be at a cognitive disadvantage during early development.

Interventions aimed at changing biochemical and physiological regulation in at-risk infants.

A previous study conducted by Feldman and Eidelman (2003) examined effects of breast milk on premature infants. Interestingly, the study found that both high amounts of breast milk and the presence of maternal affectionate touch served to enhance infant mental development scores. In the present study, both breastfeeding groups displayed the highest amounts of maternal affectionate touch of all four groups. Breastfeeding is not only neuroprotective against depressive symptoms, but the breastfed infants are also predisposed to display superior mental development in comparison to bottle-fed populations. The results of the study also reveal that breastfeeding facilitates maternal affectionate touch. Maternal affectionate touch is also critical for the synchrony of mother-infant communication especially in at-risk populations.

It was hypothesized that only the infants of depressed, breastfeeding mothers would show a shift in EEG asymmetry, but in fact the three groups, excluding the depressed, bottle-feeding groups, displayed a right to left EEG shift. Infants of depressed mothers are at a higher risk for developing depression themselves because of both genetic and environmental influences (Rice, Harold, and Thapar, 2005). Both depressed groups possess a genetic predisposition for depression. In the present study infants of the depressed, bottle-feeding mothers were more vulnerable to environmental interactions because they were not exposed to buffers, such as breastfeeding, which inhibit the environmental transmission of depression. The environmental influences of the infants of depressed, bottle-feeding mothers negatively affected emotional development, thus inhibiting mother-infant communication.

Other studies have linked maternal depression to suboptimal interactive styles of mother-child dyads into the child's preschool years. One study found depressed mothers, although verbally expressive to their children, did not exhibit high levels of nonverbal communication (Hwa-Froelich, Cook, & Flick, 2008). Non-depressed mothers were more likely to interact with their children using forms of communication other than verbalizations, such as gaze, touch, and physical proximity. Although this study used low-income mothers and is not generalizable to other maternal populations, it does provide insight to the persistence of impaired mother-infant communication in depressed dyads. Infancy establishes the interactive styles of mother and child and communication styles likely remain stable as the infant ages.

Future Research

When examining the differences in feeding status only, differences found between the non-depressed breast- and bottle-feeding mothers may be accounted for by maternal self-selecting behaviors. Mothers who choose to breastfeed are often more confident in their maternal capabilities than mothers who choose to bottle-feed (Otsuka, Dinnis, Tatsuoka, & Jimba, 2008; Semenic, Loiselle, & Gottlieb, 2008). Breast-feeding mothers may therefore possess a stronger inclination to interact affectionately with their infants than bottle-feeding mothers through acquired motivation; first possessing high maternal qualities and then an initiation of desire to continue breastfeeding (Myers & Siegel, 1985). The bottle-feeding mothers, however, do not have the advantage of being exposed to the levels of hormones associated with breastfeeding. Educating mothers about the advantages of breastfeeding as a low-cost intervention strategy for at-risk populations, is especially important for mothers exhibiting depressive symptoms.

A recent study by Schmidt and colleagues (2009) established a link between the dopamine D4 receptor (DRD4) gene, mid-frontal EEG asymmetry patterns, and infant temperament. The long allele of the DRD4 gene has recently been linked to approach behaviors and soothability as well as contrasting findings relating the gene to attentional deficits in infants and children. The researchers found the long allele of the DRD4 gene to be linked to both high and low soothability scores of infants and also attentional deficits. EEG asymmetry of the infants was found to be the moderating factor in which greater relative right frontal asymmetry was linked to low soothability and attentional scores and greater left frontal activity was linked to higher soothability scores at 48 months. The differences in expression of the gene demonstrate a susceptibility to gene-environment interactions. Thus, an infant possessing endogenous susceptibility to adverse environmental situations is more likely to be affected by a tendency to express EEG patterns consistent with withdrawal behaviors.

The effects breastfeeding and maternal depression have upon endogenous expression of the long allele of the DRD4 gene has not yet been studied. However, future studies may address the likelihood of inheriting the gene from mothers with psychopathologies such as depression. Furthermore, in the present study breastfeeding produced a right to left frontal hemispheric switch in infants of depressed mothers. It may also serve as a neuroprotective measure against susceptibility to inherited genes as well as prenatal hormonal influences.

Limitations

Recruiting depressed mothers to participate short-term longitudinal studies creates complications because of their high attrition rate. Therefore, the tendency for depressed mothers to drop out of studies is in itself an expression of depressive mood. It would be expected that if these mothers had persisted in the study, the results for the depressed groups would have displayed statistical significance when compared to the other groups. Mothers suffering from depression are more likely to bottle feed their infants than breastfeed, therefore depressed mothers who breastfeed may differ from all three groups for various reasons. Variables driving touch patterns and infant brain development in the depressed, breastfeeding group may be due to maternal compensation factors making the group unlike the other dyads.

The classifications of feeding status also limited the touch behavior analyses. The classification of the feeding groups was conservative in that only exclusive breastfeeding mothers were assigned to the breastfeeding group. Mothers who occasionally supplement breast milk with formula were considered bottle feeding mothers in the present study. These mothers and their infants may differ in tactile behaviors than mothers who exclusively bottle feed. Future studies may utilize a more comprehensive classification of feeding status to include mothers who employ both methods of feeding to examine whether their behaviors are more similar to breastfeeding mothers or bottle feeding mothers.

It is also important to note the limitations of measuring frontal activation using the EEG in young infants. The frontal region is not developed at 1 month of age therefore EEG recordings may reflect subcortical activity rather than cortical activity. Shifts in EEG asymmetry scores may also be indicative of brain development. Therefore, EEG recordings must be interpreted by the researcher with caution as alternative explanations for EEG patterns in infants exist.

Concluding Remarks

The present study attempted to address the touch and physiological differences in feeding groups within the context of maternal depression. Breastfeeding should be looked at as an effective and viable low-cost intervention to facilitate bonding within the dyad and perhaps even alleviate maternal depressive symptoms. Furthermore, infants of depressed breastfeeding mothers did not exhibit the same patterns of brain activity and behavior as the infants of depressed, bottle feeding mothers. Breastfeeding stimulated enhanced touch patterns which lead to optimal interactive patterns, even in those with maternal depression. In fact, the infants of depressed, breastfeeding mothers showed neither behavioral nor brain development impairment as a function of depression. The measures of mother-infant communication in the present study demonstrate the importance of breastfeeding in the establishment of mother-infant communication, not only in depressed groups but in normal populations as well.

Table 1

Second by second coding of Infant Tactile Behaviors   Cohen's κ = .92

Code	Behavior Description
7	**Stroke**- (rub, caress, wipe) Lateral finger movement (back and forth or circular); often repetitive. If just tip of finger is moving, finger category is used
6	**Finger**- (manipulate) Running the tip of the fingers over a surface, often in random fashion
5	**Static**- Hand remains still while in contact with a stimulus (can include static grab)
4	**No Touch**- Hand not in contact with anything
3	**Pat**- (tap) Up and down motion of the hand against a surface
2	**Pull**- (push, lift) - Raising/lowering of a stimulus or exerting pressure against an object
1	**Grab**- (clutch, clasp) Curling of fingers around a stimulus, active grab

Table 2

Second by second coding of Infant Touch Location   Cohen's κ = .85

Code	Behavior Description
6	**Face/Head/Shoulder/Neck**- Touching any region of the face or neck/shoulder region with the exception of the mouth
5	**Mouth**- Touching of the inside or outside of the mouth, including the lips
4	**Body-** Touching any region of the trunk and/or limbs including clothing
3	**Mother**- Touching of any part of the mother, including her hands, face, hair, clothes, etc.
2	**Other-** Touching anywhere other than the mother or self
1	**No Area**- Hand not in contact with anything

Table 3

Second by second coding of Maternal Tactile Behaviors   Cohen's $\kappa = .95$

Code	Behavior Description
7	**Affectionate Firm Touch**- firm patting, stroking, massaging with the whole hand; non-aggressive, affectionate; not poking infant
6	**Light Active Touch**- affectionate kissing, caressing, or stroking, grazing, affectionately comforting, hugging
5	**Passive Touch**- passive contact, resting the hand in contact with the infant, comforting presence for infant without interrupting flow of attention; static skin-to-skin contact
4	**Not affectionate/passive/reactive-** Any form of maternal touch which does not fall into the affectionate, passive, or reactive touch categories (Please define how the mother touches the infant)
3	**No touch**- mother is not touching the infant
2	**Awkward Handling-** holding the child in an uncomfortable manner with an uninterested or neglectful attitude
1	**Rough Handling**- exercising forceful or abrupt restraint or physical control of the child with an angry or punitive quality

Table 4

Second by second coding of Maternal Active Behaviors Cohen's κ = .95

Code	Behavior Description
5	**Vestibular Stimulation**- movements that change the infant's orientation in space; repositioning, swaying, rocking, lifting,
4	**Matter-of-fact Touch**- purposeful utilitarian contact; ex. wiping the child's mouth eye; moving infant's hand if interfering with feeding
3	**Proprioceptive Stimulation**- flexion and extension of the infant's limbs, often used during dressing
2	**No Active Touch-** No active maternal touch present, but the mother still touches the infant
1	**No Touch**- The mother is not in contact with the infant

Table 5

Second by second coding of Infant Gaze Cohen's $\kappa = .78$

Code	**Behavior Description**
3	Infant gazes at mother
2	Infant gazes elsewhere
1	Infant has eyes closed/Infant is sleeping

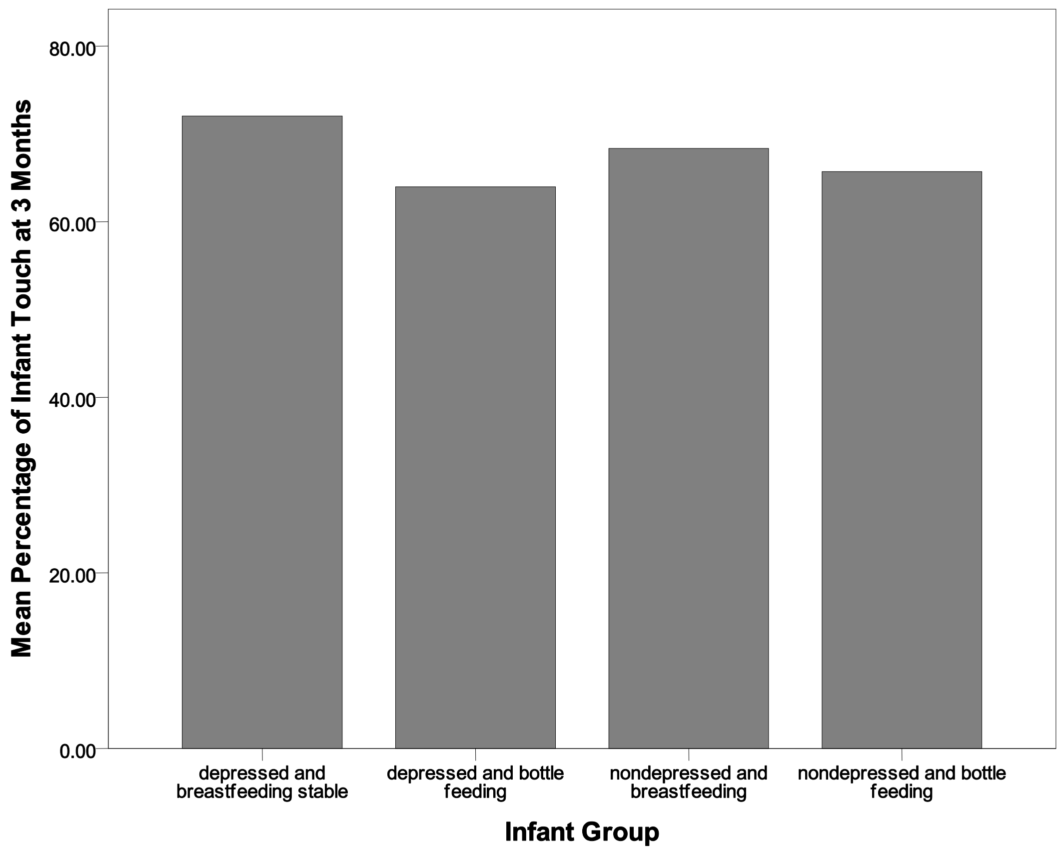

Figure 1. The mean percent of time (over a 5 minute period) the four infant groups engaged in tactile behaviors during a feeding session at the 3 –month lab visit.

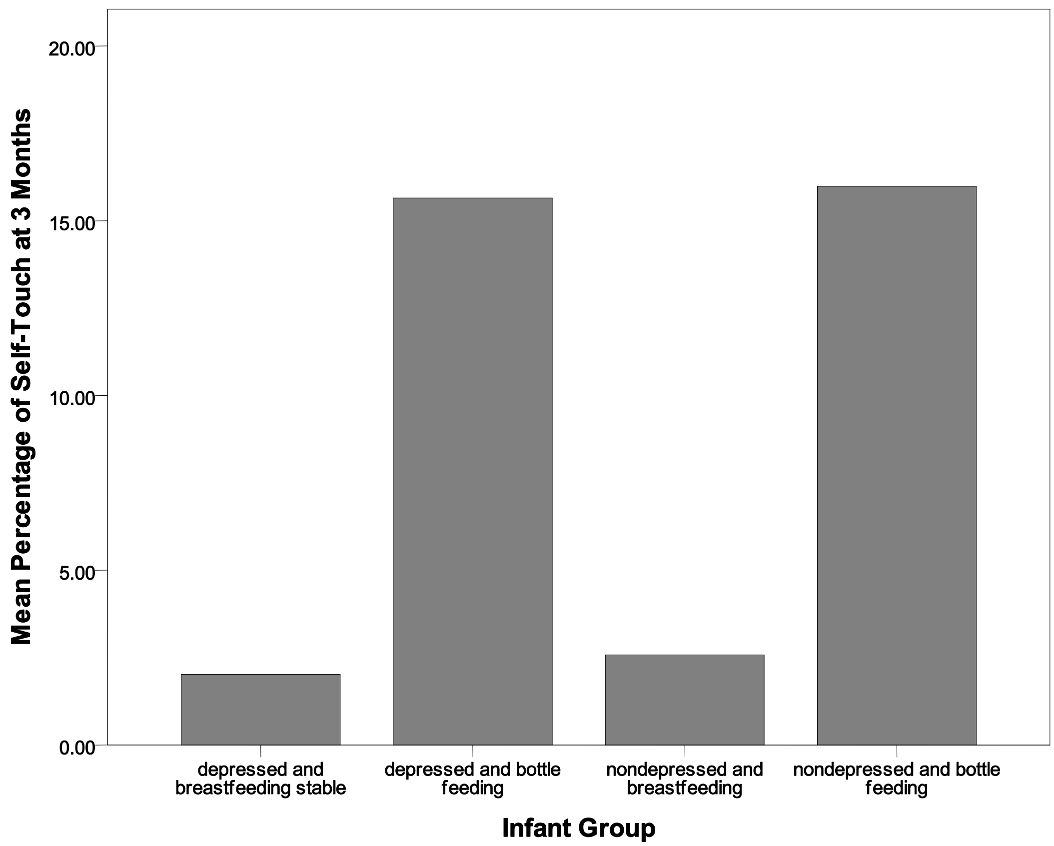

Figure 2. The mean percent of time (over a 5 minute period) the four infant groups engaged in self-touch behaviors during a feeding session at the 3 –month lab visit.

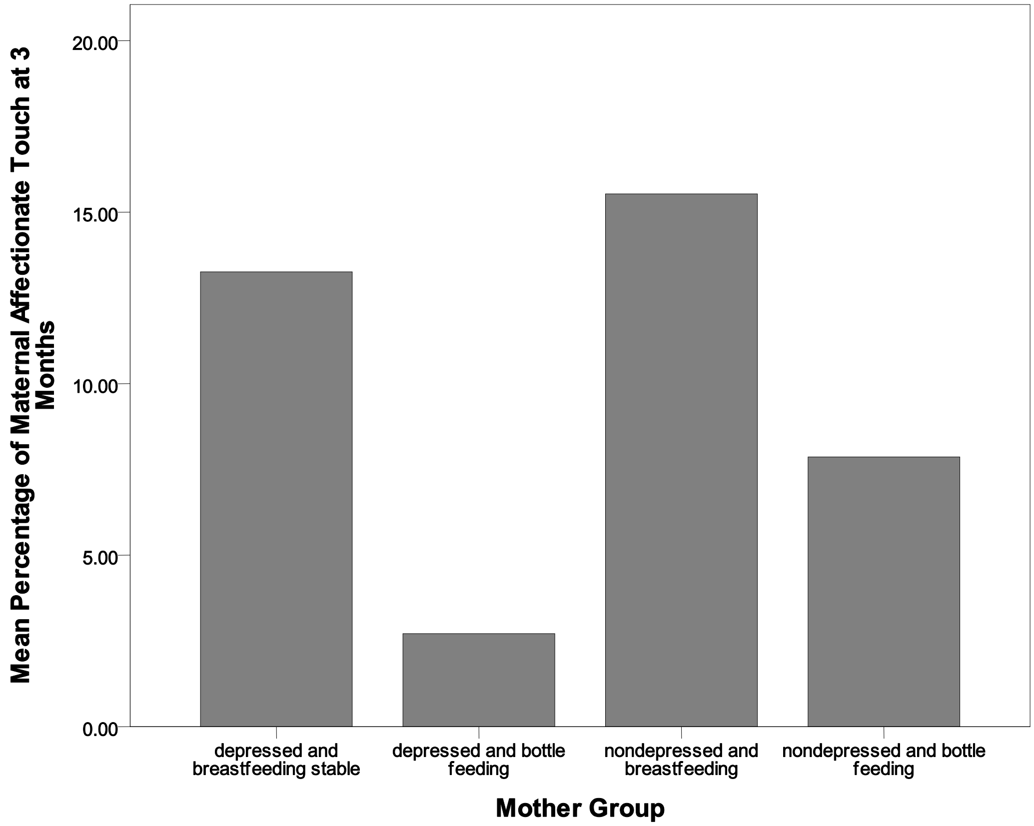

Figure 3. The mean percent of time (over a 5 minute period) the four mother groups engaged in affectionate tactile behaviors during a feeding session at the 3 –month lab visit.

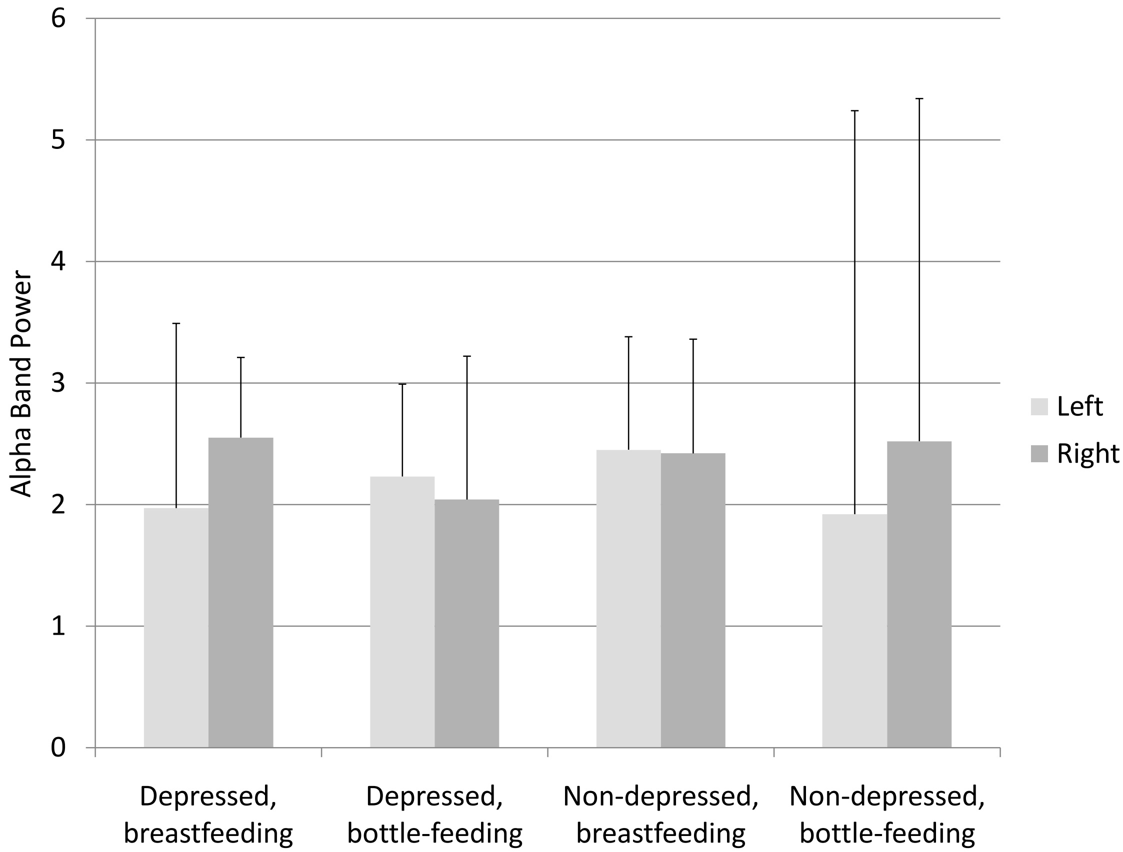

Figure 4. Alpha power is inversely related to hemispheric activation, indicating the the infants of depressed, bottle-feeding mothers and the infants of non-depressed breastfeeding mothers showed the least amount of left hemispheric activity and the greatest amount of right hemispheric activity

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