THE ROLE OF POSITIVE EMOTIONS IN PERINATAL MENTAL HEALTH AND BREASTFEEDING

Kathryn Gwinn Wouk

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Approved by:

Alison M Stuebe

Brian Pence

Samantha Meltzer-Brody

Christine Tucker

Bharathi Zvara

ABSTRACT

Kathryn Gwinn Wouk: The Role of Positive Emotions in Perinatal Mental Health and Breastfeeding
(Under the direction of Alison M Stuebe)

Major medical organizations in the U.S. recommend exclusive breastfeeding for six months, with continued breastfeeding through the first year or longer as desired by the woman and her infant. Public health programs have primarily aimed to increase breastfeeding duration and exclusivity without addressing the emotional experience of breastfeeding. Barbara Fredrickson's broaden-and-build theory of positive emotions suggests that experiences of positive emotions lead to adaptive benefits by broadening thoughts and actions, facilitating the accrual of resources to improve health and well-being. In the context of the postpartum, this theory suggests that positive emotions experienced during infant feeding may broaden the scope of a mother's thoughts and actions, allowing her to build resources to cope with challenges.

We used longitudinal data from the Mood, Mother and Infant cohort of women followed from the third trimester across the first year postpartum to test the extent to which positive emotions during infant feeding were associated with postpartum depression and anxiety and breastfeeding outcomes. We used generalized linear mixed effects models and time-to-event analyses to explore these associations, exploring modification by women's baseline psychopathology.

Among women without a diagnosis of prenatal depression, positive emotions during feeding were inversely associated with postpartum depression symptoms. On the other hand, among women with a diagnosis of prenatal anxiety, positive emotions were associated with

significantly lower postpartum anxiety symptoms. We speculate that women with prenatal anxiety who neverthess enjoy the experience of infant feeding may benefit from anxiolytic effects of oxytocin during breastfeeding and mother-infant interaction.

Positive emotions were not significantly associated with time to any breast milk feeding cessation; however, positive emotions were significantly associated with a longer time to exclusive breast milk feeding cessation and with a better overall maternal breastfeeding experience, especially with dimensions of maternal enjoyment, role attainment, and lifestyle compatibility. Positive feelings about breastfeeding in the first week were similarly associated with breastfeeding outcomes, suggesting the importance of the early maternal experience of breastfeeding on long-term outcomes.

Mother-centered programs and policies that support the experiential aspects of infant feeding may improve postpartum mental health, breastfeeding rates, and maternal satisfaction with breastfeeding.

I dedicate this work to Niles Newton and Juno Wouk, who share an abiding concern for the mama.

"As feminists we should affirm the value of nurturing; an ethic of caring does indeed hold promise for a more human justice, and political values guided by such an ethic would change the character of the public for the better. But we must also insist that nurturers need, that love is partly selfish, and that a woman deserves her own irreducible pleasures."

—Iris Marion Young

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The ten representative positive emotions included on the modified Differential Emotions Scale are not only useful for data collection, but also for organizing one's dissertation acknowledgements:

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change systems for the better. I have so much hope for the future because of the women speaking up, running for office, and taking care of one another. Niles Newton's legacy in is capable hands.

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criteria
BDI-II	Beck Depression Inventory II
BFHI	Baby-Friendly Hospital Initiative
BIC	Bayesian Information Criteria
CTQ	Childhood Trauma Questionnaire
ECR-S	Experience in Close Relationship Scale-Short Form
EITQ	Carey Early Infancy Temperament Questionnaire
EMA	Ecological momentary assessment
EPDS	Edinburgh Postnatal Depression Scale
GAD	Generalized Anxiety Disorder
LKM	Loving Kindness Meditation
LRT	Likelihood Ratio Test
MAAS	Maternal Antenatal Attachment Scale
MBFES	Maternal Breastfeeding Evaluation Scale
mDES	modified Differential Emotions Scale
MOS	Medical Outcomes Study Social Support Survey
SCID	Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders-IV
STAI-S	Spielberger State-Trait Anxiety Inventory-State Subscale
WHO	World Health Organization

CHAPTER 1 - INTRODUCTION

Specific Aims

Perinatal depression is one of the most prevalent complications of childbirth, affecting approximately one in seven women during pregnancy and the first year postpartum (Gaynes et al., 2005). Untreated perinatal depression is associated with numerous adverse outcomes including early breastfeeding cessation (Dennis & McQueen, 2009; Dias & Figueiredo, 2014), impaired mother-infant attachment (Campbell, Matestic, von Stauffenberg, Mohan, & Kirchner, 2007), and serious child social and emotional developmental concerns (Stein et al., 2014; Trapolini, McMahon, & Ungerer, 2007). While prenatal depression symptoms may disrupt breastfeeding and exacerbate postpartum mood and anxiety (Dias & Figueiredo, 2014; Ystrom, 2012), research shows that individuals can reduce depression symptoms and build personal resources, such as social support and mindfulness, by increasing experiences of positive emotions (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008). However, the role of positive emotions in perinatal mental health and breastfeeding outcomes has not yet been explored.

The long-term goal of this research is to leverage positive emotions to improve perinatal mental health and breastfeeding for the well being of mothers and infants. The objective of this dissertation is to determine the extent to which experiences of positive emotions during infant feeding are associated with both postpartum depression and anxiety symptoms and breastfeeding outcomes, indexed by duration, exclusivity, and maternal experience. The central hypothesis of this research is that women who report more experiences of positive emotions during infant feeding will have fewer postpartum depression and anxiety symptoms and sustain longer breast

milk feeding across the first year postpartum compared with women who report fewer positive emotions. The rationale for this proposed research draws from evidence for the association between perinatal mood and anxiety and lactation difficulties (Stuebe, Grewen, Pedersen, Propper, & Meltzer-Brody, 2012), as well as Barbara Fredrickson's broaden-and-build theory of positive emotions, which posits that experiences of positive emotions trigger upward spirals that improve mental health and wellbeing (Fredrickson, 2004). Applied in a variety of intervention contexts, this theory has demonstrated that cultivation of positive emotions through a loving-kindness meditation intervention leads to reduced depression symptoms (Fredrickson et al., 2008), increased perception of social connections (Kok et al., 2013), and increased life satisfaction (Johnson et al., 2011).

We will test the above hypothesis and accomplish the objective of this dissertation by pursuing the following specific aims:

Aim 1. Estimate the association between positive emotions during infant feeding at two months postpartum and depression and anxiety symptoms at months 2, 6, and 12.

1a. Explore modification of these associations by maternal psychopathology at baseline.

Aim 2. Estimate the association between positive emotions during infant feeding at two months and time to any and exclusive breast milk feeding cessation across months 3-12 as well as maternal evaluation of the overall breastfeeding experience at 12 months.

2a. Explore modification of these associations by maternal psychopathology at baseline.

2b. Repeat analyses using maternal feelings about breastfeeding in the first week postpartum as the exposure of interest to address potential selection bias in main

analyses due to exclusion of women who discontinue breastfeeding by two months.

By achieving these aims, this research will lay the foundation for understanding the role of positive emotions in perinatal mental health and breastfeeding outcomes. These results will have a positive impact by informing the future development of positive psychology interventions and mother-focused infant feeding support designed to improve postpartum mental health and breastfeeding outcomes.

Background and Significance

Perinatal depression and anxiety are the most common complications of pregnancy

Depression is the primary cause of disease-related disability in women (Noble, 2005), with a lifetime prevalence of approximately 23.1% (Kessler, McGonagle, Swartz, Blazer, & Nelson, 1993). The lifetime prevalence of anxiety disorders is nearly twice as high for woman as men, at 18.5% versus 10.4% (Somers, Goldner, Waraocj, & Hsu, 2006). Perinatal depression and anxiety are the most common complications of childbirth (O'Hara & Swain, 1996; Sockol, Epperson, & Barber, 2011), frequently presenting as comorbid symptoms (Grigoriadis et al., 2011; Matthey, Barnett, Howie, & Kavanagh, 2003; Wenzel, Haugen, Jackson, & Brendle, 2005). According to the Diagnostic and Statistic Manual of Mental Disorders Fifth Edition (DSM-V), major depressive disorder requires endorsing at least five of nine symptoms, including feeling sad, hopeless, or worthless, as well as several symptoms shared with generalized anxiety disorder (GAD), such as fatigue, sleep disturbance, and difficulty concentrating (American Psychiatric Association, 2013).

The prevalence and incidence estimates of perinatal depression and anxiety vary widely across studies, depending on the time period over which the condition is defined, the clinical

instrument used to assess symptomology, and the type and number of criteria required for diagnosis. Estimates are generally elevated where symptoms are determined using self-report scales without structured interviews for diagnosis (Bennett, Einarson, Taddio, Koren, & Einarson, 2004). A systematic review conducted for the Agency for Healthcare Research and Quality (AHRQ) that required a clinical assessment or structured clinical interview for diagnosis estimated the prevalence of major and minor depression to be 18.4% during pregnancy and 19.2% in the first three months after birth, with approximately 14.5% of women experiencing incident depression during each period (Gavin et al., 2005). Because the greatest risk of outpatient contact or hospital admission for any postpartum mental disorder occurs during the first month after birth (Munk-Olsen, Laursen, Pedersen, Mors, & Mortensen, 2006), the DSM-V defines depression "with peripartum onset" as a mental disorder if it occurs during pregnancy or the first month postpartum; however, the elevated risk of psychiatric hospital admission for any mental disorder persists across the first three months after delivery (Munk-Olsen et al., 2006), and about 8% of women continue to exhibit depression symptoms beyond the first year postpartum (Dennis, Heaman, & Vigod, 2012). The severity of symptoms also varies by timing of onset, as women who report prenatal onset are more likely to have both a history of depression or anxiety and to experience more severe postpartum symptoms than women reporting postpartum onset (Postpartum Depression: Action Towards Causes and Treatment (PACT) Consortium, 2015).

The evidence for estimating the prevalence of perinatal anxiety is more limited, with many studies ascertaining anxiety symptoms through self-report questionnaires (Wenzel & Stuart, 2011). A recent study following a Canadian cohort of 310 women found approximately 15.8% of women experienced a SCID-diagnosed anxiety disorder during pregnancy and 17.1%

received a diagnosis during the first three months postpartum (Fairbrother, Janssen, Antony, Tucker, & Young, 2016). Another study conducted among 497 pregnant women in France found a similar percentage of 24.1% had at least one anxiety disorder, with approximately 8.5% receiving a diagnosis of GAD using the Mini International Neuropsychiatric Interview (Sutter-Dallay, Giaconne-Marcesche, Glatigny-Dallay, & Verdoux, 2004). A study of postpartum anxiety symptoms using the Beck Anxiety Inventory in a community sample in Iowa found the prevalence to be 8.7% at 14 weeks postpartum and 16.8% at 30 weeks postpartum, suggesting an increase in anxiety symptoms in the postpartum period (Stuart, Couser, Schilder, O'Hara, & Gorman, 1998). Another study using the SCID to diagnose GAD at eight weeks postpartum found only 4.4% met criteria for GAD while 27.9% had subsyndromal generalized anxiety symptoms (Wenzel, Haugen, Jackson, & Robinson, 2003). Additionally, slightly more than half of women experiencing anxiety symptoms reported onset during pregnancy, and these women were more likely to have a history of psychopathology and treatment compared with women whose symptoms began in the postpartum period (Wenzel et al., 2003). Women with prenatal anxiety symptoms also have a significantly increased risk of experiencing postpartum depression (Austin, Tully, & Parker, 2007; Heron, O'Connor, Evans, Golding, & Glover, 2004).

Both the lack of routine screening and the stigma associated with perinatal depression and anxiety contribute to underestimates of prevalence and incidence. One systematic review found that women across diverse cultures do not independently seek help for postpartum depression symptoms, especially where health care access is limited or health care providers lack effective treatment or referral skills (Dennis & Chung-Lee, 2006). Studies have shown that less than 50% of women with perinatal depression or anxiety symptoms seek treatment (Vesga-Lopez & Blanco, 2008), have their symptoms detected by health care providers during the perinatal

period (Cox, Sowa, Meltzer-Brody, & Gaynes, 2016; Goodman & Tyer-viola, 2010), or receive a diagnosis for self-reported symptoms (Ko, Farr, Dietz, & Robbins, 2012). One study using medical records to confirm detection, treatment, and referral rates by obstetrical providers found that referral or treatment occurred among only 33% of women who screened positive for depression or anxiety during pregnancy and 27.5% of those who screened positive at six weeks postpartum (Goodman & Tyer-viola, 2010). Additionally, only 50% of those who were referred for treatment accessed this care (Goodman & Tyer-viola, 2010), due to barriers such as lack of time, stigma, and child care issues (Goodman, 2009). These barriers to identification and referral lead many symptomatic women to remain untreated or undertreated during the vulnerable perinatal period, underscoring the need for effective prevention strategies.

Despite a multitude of evidence supporting the efficacy of pharmacological treatment (Meltzer-Brody, 2011), many pregnant and breastfeeding women, along with their medical providers, also fear medication-based treatment due to concerns about drug exposure to the fetus or nursing infant (Battle, Salisbury, Schofield, & Ortiz-Hernandez, 2013; Dimidjian & Goodman, 2009; Pearlstein et al., 2006). Women's preferences for non-pharmacological treatments while pregnant or breastfeeding, along with the issue of low detection of symptomatic women, support the critical need for research into non-medical prevention options for perinatal depression and anxiety symptoms.

Predictors of perinatal depression and anxiety include psychiatric, psychosocial, demographic, and childbirth-related risk factors

Strong predictors of postpartum depression include a history of depression, prenatal depression and anxiety, low self-esteem, stressful life events, poor marital relationship, and lack of social support (Lancaster et al., 2010; O'Hara, 2013; Robertson, Grace, Wallington, &

Stewart, 2004; Silverman et al., 2017). Moderate risk factors for postpartum depression include low socioeconomic status, unwanted pregnancy, and difficult infant temperament (C. T. Beck, 2001; Norhayati, Nik Hazlina, Asrenee, & Wan Emilin, 2015; O'Hara, 2013). Low-income women have been shown to have approximately two times the prevalence of both general depression (Scholle, Haskett, Hanusa, Pincus, & Kupfer, 2003) and perinatal depression compared with middle-class women (Hobfoll, Ritter, Lavin, Hulsizer, & Cameron, 1995). The role of race/ethnicity as a predictor of perinatal depression is less well understood, as many studies are conducted in nonminority samples; differences in symptomology by race have generally been diminished after controlling for socioeconomic characteristics, indicating that structural racism and poverty may be underlying predictors (Beeghly et al., 2003; Hobfoll et al., 1995; Zayas, Cunningham, McKee, & Jankowski, 2002).

While less evidence is available to identify specific risk factors for perinatal anxiety, the extant literature indicates some predisposing factors shared with perinatal depression symptoms, including low social support and socioeconomic status, stressful life events (Biaggi, Conroy, Pawlby, & Pariante, 2016), and early postpartum return to work (Chatterji & Markowitz, 2003; Dagher, McGovern, & Dowd, 2014; Gjerdingen & Chaloner, 1994). Childhood trauma is associated with both postpartum depression and anxiety symptoms (Huh, Kim, Yu, & Chae, 2014; Meltzer-Brody, Boschloo, Jones, Sullivan, & Penninx, 2013; Sexton, Hamilton, McGinnis, Rosenblum, & Muzik, 2014). A history of depression or anxiety disorders and current depression are considered strong predictors of perinatal anxiety (Biaggi et al., 2016; Wenzel & Stuart, 2011). In one study, pre-pregnancy anxiety appeared to be a stronger predictor, with 65.6% of women with a history of anxiety disorder experiencing postpartum depression/anxiety compared with 29.4% of women with a history of depressive disorder (Matthey et al., 2003). Some women

may be particularly vulnerable to the significant hormonal fluctuations during pregnancy and the postpartum (Cowley & Roy-Byrne, 1989; Glover & Kammerer, 2004; Ross, Sellers, Gilbert Evans, & Romach, 2004), which can dysregulate the stress system of the brain known as the hypothalamic pituitary adrenal (HPA) axis (Jolley & Spach, 2008). Perinatal loss and childbirth complications can also complicate existing anxiety symptoms or trigger incident postpartum anxiety symptoms (Janssen, Cuisinier, Hoogduin, & de Graauw, 1996; Paul, Downs, Schaefer, Beiler, & Weisman, 2013).

Risk factors for incident depression and anxiety may differ from those that lead to more persistent forms. While a history of depression is a strong predictor of perinatal depression, a study using Finnish health registers found that approximately 50% of those depressed during pregnancy experienced incident depression (Räisänen et al., 2014). Another study found different risks for future postpartum and non-perinatal depression episodes between women whose postpartum depression represented their first onset of depression versus recurrent depression (Cooper & Murray, 1995). According to this study, 56% of women experiencing incident depression in the postpartum period had a subsequent episode of depression during the three and half-year follow-up after delivery, while 67% of women experiencing recurrent depression had a subsequent episode. However, women experiencing incident depression had much higher prevalence of recurrent postpartum depression (Cooper & Murray, 1995). Similarly, Spielberger et al. has distinguished between trait anxiety, or an individual's dispositional proneness to anxiety, and state anxiety, or the acute emotional arousal in response to perceived stress or danger (Spielberger, Gorsuch, & Lushene, 1970). Women with a history of anxiety or depression are more likely to experience perinatal state anxiety, though a family psychiatric history has not been shown to increase this risk (Breitkopf et al., 2006; Wenzel et al., 2005). These limited

studies suggest that women experiencing chronic versus incident perinatal depression/anxiety symptoms may have different susceptibilities to the psychological and physical changes associated with childbirth.

Perinatal depression and anxiety are associated with a number of adverse outcomes

Potential adverse outcomes associated with untreated perinatal depression and anxiety include preterm birth (Grote et al., 2010), disrupted lactation (Hahn-Holbrook, Haselton, Dunkel Schetter, & Glynn, 2013; Paul et al., 2013; Stuebe et al., 2014), and child emotional, cognitive, and behavior problems (Kingston & Tough, 2013; Netsi et al., 2018; O'Donnell, Glover, Barker, & O'Connor, 2014). Possible mechanisms linking prenatal depression and anxiety symptoms with infant and child health outcomes include physiological factors, such as elevated cortisol (Bergman, Sarkar, Glover, & O'Connor, 2010; O'Donnell et al., 2014) and unhealthy prenatal practices, such as smoking, illicit substance abuse, and poor nutrition (Marcus & Heringhausen, 2009) that may affect both fetal development and longer term health outcomes through fetal programming (O'Donnell et al., 2014). Postpartum depression has also been implicated in child development, behavior, and mental health through associations with maternal sensitivity, positivity, and responsiveness to infant needs (Campbell et al., 2007; Swain et al., 2014). Additionally, a history of depression and anxiety disorders as well as depressed mood during the perinatal period are associated with an increased risk of suicide (Gold, Singh, Marcus, & Palladino, 2012), which accounts for approximately 20% of maternal deaths (Lindahl, Pearson, & Colpe, 2005).

Women in the US face many barriers to breastfeeding

Breastfeeding is associated with a number of well-established health benefits for both mothers and infants. For infants, breastfeeding is associated with a decreased risk of infections

(Ip et al., 2007), all-cause mortality (Sankar et al., 2015), and chronic diseases such as type 2 diabetes (Horta, de Mola, & Victora, 2015b), as well as higher performance on intelligence tests (Horta, de Mola, & Victora, 2015a). For mothers, breastfeeding is associated with a decreased risk of breast and ovarian cancers (Victora et al., 2016), type 2 diabetes (Chowdhury et al., 2015), hypertension (Stuebe et al., 2011), and cardiovascular disease (Gunderson et al., 2015). As a result of these benefits, the American Academy of Pediatrics, American College of Obstetricians and Gynecologists, and American Academy of Family Physicians all recommend exclusive breastfeeding for six months, with continued breastfeeding alongside complementary foods for one year or longer (American Academy of Family Physicians, 2014; American Academy of Pediatrics Section on Breastfeeding, 2012; The American College of Obstetricians and Gynecologists, 2016).

In the US, approximately 82.5% of women initiated breastfeeding in 2014, indicating a widespread desire to breastfeed; however, only 24.9% of women reported exclusive breastfeeding at six months and only 33.7% reported any breastfeeding at one year (Centers for Disease Control and Prevention, 2017). These duration and exclusivity estimates fall short of both professional recommendations and Healthy People 2020 targets, which aim to increase the percentage of women exclusive breastfeeding at six months to 25.5% and any breastfeeding at one year to 34.1% (US Department of Health and Human Services, 2012). Risk factors for suboptimal breastfeeding include early lactation problems, such as milk supply, pain, and latch concerns (Chantry, 2011; Odom, Li, Scanlon, Perrine, & Grummer-Strawn, 2013); low socioeconomic status (Mitra, Khoury, Hinton, & Carothers, 2004; Taveras et al., 2003; U.S. Department of Health and Human Services, 2011); low self-efficacy (Henshaw, Fried, Siskind, Newhouse, & Cooper, 2015; Meedya, Fahy, & Kable, 2010); lack of adequate maternity leave

(Johnston & Esposito, 2007; Taveras et al., 2003); lack of adequate social or spousal support (Bai, Middlestadt, Peng, & Fly, 2010; Mitra et al., 2004); and history of mood or anxiety disorders (Figueiredo, Canário, & Field, 2014; Wallwiener et al., 2015).

The term "breastfeeding" comprises a number of different mother-infant behaviors that include significant variation in the amount of breast milk consumed by an infant. This variation contributes to inconsistent measurement of breastfeeding across studies and difficulty in comparing the benefits associated with such heterogeneous behaviors. The World Health Organization (WHO) defines "breastfeeding" where a child recives any breast milk, either direct from the breast or expressed, and "exclusive breastfeeding" where a child recives only breast milk, either from the mother, a wet nurse, or as expressed milk, and no other liquids or solids with the exeption of vitamins, mineral supplements, and medications (Labbok & Starling, 2012). Existing definitions of breastfeeding based on infant intake alone exclude the experiential and process-oriented maternal aspects of breastfeeding (Auerbach, 1991).

Breastfeeding and perinatal mental health appear to be associated

An association between early breastfeeding cessation and perinatal depression symptoms has been observed across numerous studies (Dennis & McQueen, 2009; Dias & Figueiredo, 2014), though the directionality of this association remains unclear. Two systematic reviews have identified extensive evidence that both prenatal and postpartum depression symptoms are associated with reduced breastfeeding duration (Dennis & McQueen, 2009; Dias & Figueiredo, 2014), and there is preliminary evidence for an association with lower breastfeeding exclusivity (Figueiredo et al., 2014; Flores-Quijano et al., 2008; McCarter-Spaulding & Horowitz, 2007). When compared to bottle-feeding mothers, breastfeeding mothers report fewer depression symptoms (Figueiredo et al., 2014; Gross, Wells, Radigan-Garcia, & Dietz, 2002; Mancini,

Carlson, & Albers, 2007; Yonkers et al., 2001). Prenatal anxiety has been shown to be associated with a decrease in breastfeeding duration (Ystrom, 2012) and exclusivity (Mehta, Siega-Riz, Herring, Adair, & Bentley, 2012). Several studies have shown an association between postpartum anxiety symptoms and reduced breastfeeding duration (Adedinsewo et al., 2014; Paul et al., 2013; Zanardo et al., 2009) and exclusivity (Adedinsewo et al., 2014; Fallon, Christian, Halford, Bennett, & Harrold, 2017; Mehta et al., 2012; Zanardo et al., 2009). However, many of these studies are limited by vague and heterogeneous definitions of breastfeeding outcomes and perinatal mood symptoms, often measured concurrently, as well as a lack of data to control for baseline mental health.

Fewer studies have prospectively followed mothers to examine the directionality of the association between perinatal mental health and breastfeeding. One study found no association between breastfeeding at one week and depression symptoms at 4 and 8 weeks postpartum (Dennis & McQueen, 2007). Another study found that higher breastfeeding intensity at three months was associated with subsequent declines in depression symptoms through 24 months (Hahn-Holbrook et al., 2013). In one study, among women with no prenatal depression symptoms, breastfeeding was associated with a reduced risk of developing postpartum depression when women intended to breastfeed and went on to breastfeed, but an increased risk when women intended to breastfeed and did not go on to breastfeed (Borra, Iacovou, & Sevilla, 2014). Among women with prenatal depression symptoms, this association between breastfeeding as intended and postpartum depression was weaker; however, exclusive breastfeeding at four weeks was associated with lower depression scores at eight weeks postpartum, indicating a potentially protective effect of successful exclusive breastfeeding in this at-risk population (Borra et al., 2014). Ystrom found that prenatal anxiety and depression

symptoms were associated with increased breastfeeding cessation and that breastfeeding cessation was associated with later postpartum anxiety and depression symptoms; however, after adjusting for baseline mood symptoms the effect estimate for the association between breastfeeding on postpartum mental health was reduced by half (Ystrom, 2012). None of these studies reported data on participants' use of antidepressant treatments during the perinatal period, which could confound these associations.

Stuebe et al. have hypothesized that perinatal depression and early weaning may share underlying neuroendocrine causes (Stuebe et al., 2012). Mechanisms for this association include dysregulated stress reactivity (Lawrence & Lawrence, 1999; M. Newton & Newton, 1948; Stuebe et al., 2012), worries about breastfeeding (Chaudron et al., 2001), or breastfeeding difficulties (Tamminen, 1988; Watkins, Meltzer-Brody, Zolnoun, & Stuebe, 2011). Depression and anxiety symptoms are also associated with low breastfeeding self-efficacy (Flores-Quijano et al., 2008) and reduced breastfeeding intention (Fairlie, Gillman, & Rich-Edwards, 2009; Insaf et al., 2011). Antidepressant treatment for perinatal depression or anxiety treatment is associated with reduced breastfeeding due to women's concerns about infant exposure (Battle et al., 2013). Prenatal antidepressant use has been shown to be associated with reduced breastfeeding intention (Bogen, Hanusa, & Moses-kolko, 2010) and initiation (Lewis et al., 2016), and postpartum antidepressant use at two weeks with reduced breastfeeding at 12 weeks (Bogen et al., 2010). Watkins et al. found that mothers with postpartum depression symptoms at two months were both less likely to still be breastfeeding at two months and more likely to dislike breastfeeding in the first week after birth (Watkins et al., 2011). Additionally, maternal affect and emotional experiences during breastfeeding appear to be associated with postpartum depression and anxiety symptoms. This topic will be explored further in the following sections.

Conceptual Basis

The Broaden-and-Build Theory of Positive Emotions

Positive emotions are brief responses to an individual's appraisal of their current circumstances as favorable or yielding good fortune (Fredrickson, 2013). Positive emotions have generally been understudied compared with negative emotions in the field of psychology, because their expression is more diffuse than the distinctive signals and responsive actions associated with negative emotions (Ekman 1992). The primary research focus on negative emotions stems from an evolutionary approach to understanding emotions as evolved responses to life-threatening situations in which quick appraisal of and response to perceived threats promoted survival (Levenson, Ekman, & Friesen, 1990; Nesse, 1990). While positive emotions do not stimulate such autonomic responses, they have been shown to quicken the recovery from negative emotional arousal (Fredrickson, Mancuso, Branigan, & Tugade, 2000) and to broaden one's thought-action repertoire, allowing individuals to build both personal and social resources (Fredrickson, 2013). Positive affect has been shown to improve resources such as sociability, altruism, liking oneself and others, strong bodies and immune systems, and conflict resolution skills (Lyubomirsky, King, & Diener, 2005).

Fredrickson developed the broaden-and-build theory based on both correlational and prospective evidence for the effect of positive emotions on individual functioning and psychological well-being (Fredrickson, 1998, 2004). The *broaden* hypothesis posits that positive emotions broaden the scope of an individual's thoughts and actions, based on evidence of the expanded cognitive and creative context associated with experiences of positive emotions (Isen, Johnson, Mertz, & Robinson, 1985; Subramaniam & Vinogradov, 2013). The *build* hypothesis adds that this broadening effect of expansive thoughts and actions facilitates the development of

durable physical, intellectual, and social resources. For example, the experience of joy can broaden an individual's though-action repertoire by creating an urge to play, which in turn promotes skill acquisition (Boulton & Smith, 1992). Evidence from attachment theory supports this hypothesis, suggesting that early experiences of love from a caregiver allow an infant to securely pursue interest-inspired exploration (Bowlby, 1989), which is associated with the subsequent development of cognitive and social resources (Matas, Arend, & Sroufe, 1978; Sroufe, 2005).

Both discrete positive emotions and groups of related emotion families that share certain characteristics of appraisal and expression have been postulated by theorists (Ekman, 1992; Nesse & Ellsworth, 2009). In the context of these numerous constructs of positive affect, Fredrickson describes 10 representative emotions and their general appraisal patterns that have been examined in regard to mental health benefits across a number of intervention studies (Figure 1.1). One evidence-based intervention approach for increasing positive emotions is the ancient Buddhist meditation practice Loving Kindness Meditation (LKM), in which warm empathic feelings are directed toward the self and then extended to an ever-widening circle of others (Hofmann, Grossman, & Hinton, 2011). Neuroimaging studies of LKM practitioners have found evidence of neural activity in areas of the brain associated with emotional processing and empathy toward others, indicating a role of positive emotions in building relationships (Garland et al., 2010; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008). LKM practice has also been empirically shown to improve cardiac vagal tone (Kok et al., 2013), a biomarker of behavioral flexibility that is associated with maternal sensitivity to infant needs (Mills-Koonce et al., 2007).

Figure 1.1: Ten representative positive emotions assessed in the modified Differential Emotions Scale (Fredrickson, 2013)

Emotion label	Appraisal theme	Thought–action tendency	Resources accrued	Core trio in mDES item
Joy	Safe, familiar unexpectedly good	Play, get involved	Skills gained via experiential learning	Joyful, glad, or happy
Gratitude	Receive a gift or benefit	Creative urge to be prosocial	Skills for showing care, loyalty, social bonds	Grateful, appreciative, or thankful
Serenity (a.k.a., contentment)	Safe, familiar, low effort	Savor and integrate	New priorities, new views of self	Serene, content, or peaceful
Interest	Safe, novel	Explore, learn	Knowledge	Interested, alert, or curious
Hope	Fearing the worst, yearning for better	Plan for a better future	Resilience, optimism	Hopeful, optimistic, or encouraged
Pride	Socially valued achievement	Dream big	Achievement motivation	Proud, confident, or self-assured
Amusement	Nonserious social incongruity	Share joviality, laugh	Social bonds	Amused, fun-loving, or silly
Inspiration	Witness human excellence	Strive toward own higher ground	Motivation for personal growth	Inspired, uplifted, or elevated
Awe	Encounter beauty or goodness on a grand scale	Absorb and accommodate	New worldviews	Awe, wonder, amazement
Love	Any/all of the above in an interpersonal connection	Any/all of the above, with mutual care	Any/all of the above, especially social bonds	Love, closeness, or trust

Positive emotions have been linked to reduced depression and anxiety symptoms

Positive psychologists have found that positive emotions do not simply reflect good health, but rather can lead to the accrual of resources that compound over time to improve health outcomes and reduce depression symptoms (Howell, Kern, & Lyubomirsky, 2007; Pressman & Cohen, 2005). The association between positive emotions and improved mental health outcomes has been evidenced across several intervention studies. LKM practice has been shown to increase

positive emotions and reduce depression symptoms in diverse populations, including working adults (Fredrickson et al., 2008), schizophrenic patients (Johnson et al., 2011), self-critical individuals (Shahar et al., 2014), patients with chronic lower back pain (Carson et al., 2005), and veterans with posttraumatic stress disorder (D J Kearney et al., 2013). Additionally, group (Seligman, Rashid, & Parks, 2006) and individual (Taylor, Lyubomirsky, & Stein, 2016) positive psychotherapy predicted a significant reduction in depression and anxiety symptoms compared with controls. A physical activity intervention for adults led to an increase in participants' mental resources, such as increased purpose in life and positive relations with others, mediated by an increase in positive emotions (Hogan, Catalino, Mata, & Fredrickson, 2015). Two studies have shown an association between positive emotions and coping skills (A. B. Burns et al., 2008; Fredrickson & Joiner, 2002), which may also facilitate psychological well-being.

Only two studies exploring the association between positive emotions and mental health in perinatal populations were identified. A longitudinal study of 344 Norwegian mothers found that women who use positive reappraisal and planning emotion regulation strategies had fewer postpartum depression symptoms at six weeks, three months, and six months postpartum (Haga et al., 2012). One observational study of 195 women in Greece found an inverse association between self-reported experiences of positive emotions in the third trimester of pregnancy and depression symptoms measured at one week postpartum (Moraitou, Galanakis, Stalikas, & Garivaldis, 2011). While this study was limited by the lack of baseline data on women's mental health status, it identified factors such as education level, pregnancy intention, environmental and partner support, and breastfeeding difficulties to be associated with positive emotions in the early postpartum period (Moraitou et al., 2011). These two studies suggest the potential for exploring a role for experiences of positive emotions in perinatal mental health.

Preliminary evidence suggests a role for positive emotions in breastfeeding

Maternal affect and feelings toward breastfeeding have been shown to be associated with a number of breastfeeding outcomes. Three studies have found an association between positive maternal attitudes toward breastfeeding and a higher likelihood of exclusive breastfeeding in the first year postpartum, compared with ambivalent or negative attitudes (Bai et al., 2010; Scott, 2006; Semenic, Loiselle, & Gottlieb, 2008). Similarly, in an Australian cohort, maternal breastfeeding satisfaction was found to predict breastfeeding duration above and beyond breastfeeding problems (Cooke, Sheehan, & Schmied, 2003). Another study of more general maternal affect and breastfeeding outcomes found that negative maternal affect during pregnancy was associated with an increased odds of mixed breastfeeding and bottle-feeding at 6 months postpartum (Ystrom, Niegel, Klepp, & Vollrath, 2008). Two studies have shown an affect of breastfeeding on subsequent maternal affect. Mezzacappa et al. measured positive and negative maternal affect immediately after infant feeding, and found that breastfeeding mothers had a decrease in negative affect from pre to post-feeding while bottle-feeding mothers showed an increase in negative affect (Mezzacappa & Katkin, 2002). Stuebe et al. observed an increase in self-reported negative affect during infant feeding at 2 and 8 weeks postpartum among mothers with higher depression and anxiety symptoms (Stuebe, Grewen, & Meltzer-Brody, 2013a).

Additionally, several qualitative studies have investigated maternal emotions regarding their subjective interpretation of "successful" and "unsuccessful" breastfeeding. Leff et al. found that maternal enjoyment and attainment of one's desired maternal role were were identified as more important for "successful" breastfeeding than duration (Leff, Gange, & Jefferis, 1994). A meta-ethnographic synthesis of qualitative research about breastfeeding experience found that women who considered breastfeeding to be a pleasurable and enjoyable experience described the

importance of an intimate connection with the infant, maternal confidence, and appropriate support (E. Burns, Schmied, Sheehan, & Fenwick, 2010). These findings align with maternal descriptions of enjoyable breastfeeding as intimate and relational, involving both mind and body as "inseparably intertwined" (Schmied & Barclay, 1999; Spencer, 2007).

The emotional experience of infant feeding has been studied since at least 1955, when Niles Newton wrote in her dissertation: "More research which considers considers the whole nature of the breast feeding situation is badly needed. The number of months of breast feeding are probably much less important psychologically than the type of breastfeeding and the type of weaning involved. Was the breastfeeding unsuccessful breastfeeding—with all the tension, fear, and pain that that involves? Or was it successful breastfeeding with its peace of mind and physical pleasure?" (N. Newton, 1955). The emotional experience is also briefly mentioned in major U.S. breastfeeding recommendations to breastfeed through the infant's first year of life or longer "as mutually desired" by the woman and her infant (American Academy of Family Physicians, 2014; American Academy of Pediatrics Section on Breastfeeding, 2012; The American College of Obstetricians and Gynecologists, 2016). However, these recommendations only consider the relational nature of breastfeeding after one year.

Public health campaigns have focused mainly on helping women reach measurable duration and exclusivity targets, leaving the emotional experience of breastfeeding and its associated potential benefits under-explored. Additionally, evidence for the association between positive emotions and breastfeeding is limited by heterogeneous definitions of maternal emotions, ranging from measures of psychological distress (Ystrom et al., 2008) and positive versus negative emotions (Mezzacappa & Katkin, 2002; Stuebe et al., 2013a) to specific feelings or attitudes toward breastfeeding (de Jager, Skouteris, Broadbent, Amir, & Mellor, 2013;

Watkins et al., 2011). None of these studies has used the modified Differential Emotions Scale (mDES), a tool adapted by Fredrickson to examine mental and physical health benefits associated with discrete positive emotions. However, the preliminary evidence presented above establishes a conceptual basis for a possible association between positive emotions and breastfeeding that merits further exploration.

Relevance

As a result of the multiple adverse health outcomes for mothers and children described above, any intervention that could be delivered prenatally to women at risk for perinatal depression and anxiety to reduce postpartum symptomology and increase breastfeeding could yield multiple benefits for women and their families. This dissertation aims to test the extent to which experiences of positive emotions during infant feeding are associated with both mental health and breastfeeding outcomes. Such associations would support the plausibility of programs and policies that increase maternal experiences of positive emotions in order to reduce postpartum depression/anxiety and improve breastfeeding outcomes.

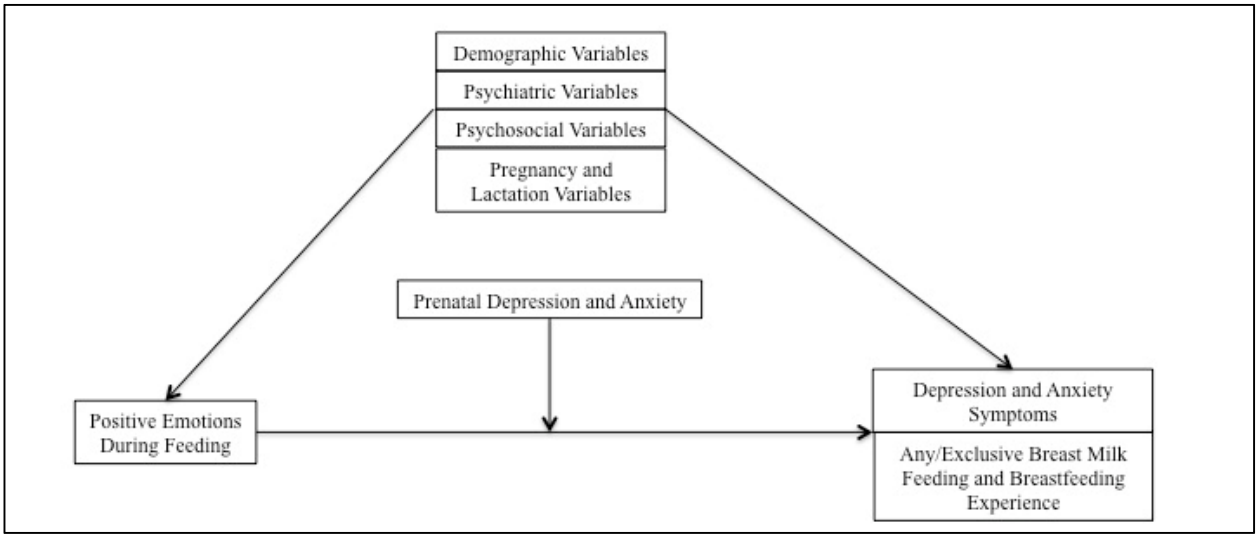
This dissertation will address a number of gaps identified in the literature reviewed above. First, it will apply both theory and experimental evidence from the field of positive psychology to explore positive emotions in a perinatal population in contrast to much of the research on perinatal processes that has generally focused on negative, stressful, and pathological effects of perinatal experiences (DiPietro, Goldshore, Kivlighan, Pater, & Costigan, 2015). The use of a structured interview for diagnosis of depression and anxiety will allow us to consider modification of our results by baseline mental health status, which is often uncontrolled in studies of perinatal mood. We will include a mother-centered outcome measure of women's affective experience of breastfeeding as an important consideration of breastfeeding success.

Through sensitivity analyses, we will also explore differences for women undergoing pharmacological treatment that might confound the association between positive emotions and mental health and breastfeeding outcomes. Finally, we will explore the association between positive emotions at two months, and a less well-validated measure of maternal feelings about breastfeeding in the first week, and time to any and exclusive breast milk feeding cessation and overall maternal evaluation of breastfeeding.

Conceptual Model

The conceptual model for this dissertation is shown below in Figure 1.2:

Figure 1.2: Conceptual model for positive emotions during infant feeding and postpartum mental health and breastfeeding outcomes



The specific hypothesized relationships between positive emotions during infant feeding and Aim 1 and Aim 2 outcomes are presented in the relevant directed acyclic graph (DAG) in the Appendix (Figure 2.1.1 and Figure 3.1.1).

Innovation

The proposed study is innovative because it 1) applies a theoretical perspective from the field of positive psychology to a population in which it has not yet been tested; 2) includes a novel measure of positive emotions during infant feeding; 3) incorporates extensive longitudinal data on women's mental health, breastfeeding, and numerous potentially confounding factors; and 4) tests associations that can provide evidence to substantiate more maternally focused programs and policies to improve outcomes across the perinatal period.

Fredrickson's broaden-and-build theory of positive emotions has not yet been tested in a perinatal population. We have adapted the mDES tool for measuring positive emotions during infant feeding as a means of testing this theory in relation to psychological and breastfeeding outcomes in the postpartum period. In this context, the broaden-and-build theory suggests that positive emotions experienced during infant feeding may broaden the scope of a mother's

thoughts and actions, allowing her to build the resources necessary to cope with mental health and breastfeeding challenges that may present during the postpartum period. Application of this theory has the potential to provide a framework for future research on positive emotions, perinatal mental health, and breastfeeding, and to balance the predominant research focus on only the negative and stressful aspects of motherhood (DiPietro et al., 2015).

The longitudinal nature of the data used for this dissertation will allow us to elucidate possible pathways between positive emotions and postpartum depression and anxiety and breastfeeding outcomes, addressing limitations of previous correlational and cross-sectional studies that cannot address the temporal order of these associations (Lyubomirsky et al., 2005). Repeat outcome measures on the cohort of women followed in-depth from the third trimester of pregnancy across the first year postpartum increase the effective sample size and precision of estimates. Monthly contact with participants from the third trimester of pregnancy through one year postpartum also provides detailed data on numerous potentially confounding variables. While causation cannot be determined from these observational data, evidence from this detailed longitudinal study can provide information regarding the potential directionality of hypothesized associations and permit us to explore modification by baseline psychopathology.

Finally, this dissertation is innovative because it aims to test the association between multiple maternal and infant outcomes and a modifiable exposure that has not yet been the target of perinatal intervention. While effective pharmacological and psychological interventions exist for perinatal mood symptoms, few treatments address mother-infant interaction (Forman et al., 2007; Letourneau, Cosic, Linder, & Dennis, 2017); increasing positive emotions during infant feeding may be a useful adjunct for medical treatment by broadening the potential benefits to

include both maternal mental health and mother-infant feeding duration, exclusivity, and affective experience.

Data and Sample

The data for this study were sourced from the NIH-funded study Mood, Mother and Infant: The Psychobiology of Impaired Dyadic Development (MMI). This longitudinal study follows approximately 220 mother-infant pairs from pregnancy through one year postpartum to examine the role of oxytocin and stress dysregulation in mediating the association between perinatal mood and insecure attachment.

Women were eligible to participate in the study if they were between 18-45 years old, 34-37 weeks gestation of a singleton pregnancy, able to communicate in English, planning to remain within 40 miles of Chapel Hill through 12 months postpartum, and intending to breastfeed greater than two months. Recruitment began with a community sample of women identified through study fliers and emails and was enriched with women at elevated risk for postpartum depression or anxiety who were approached in obstetric or psychiatric visits. Women were defined as having a low or high baseline risk for postpartum depression or anxiety, based on a SCID conducted in the third trimester of pregnancy. We classified as low risk women with no history of depression or anxiety or any current symptoms meeting a clinical threshold for diagnosis at enrollment. We classified as "high-risk" women with a SCID-confirmed depression or anxiety disorder in pregnancy or a SCID-confirmed history of depression or anxiety disorder for which they were actively being treated. The study aimed to enroll a sample comprised of approximately one-third actively depressed or anxious women, one-third asymptomatic with a history of depression or anxiety, and one-third asymptomatic with no history.

Women were excluded from the study if they met any of the following criteria: maternal diagnosis of psychiatric disorders other than depression and anxiety; history of bipolar disorder; substance use disorder; NICU admission of greater than 48 hours, major congenital anomaly, or neonatal death; current use of tricyclic antidepressants; or chronic medication/medical condition contraindicated for breastfeeding. We further excluded women who were enrolled in intervention studies that would be expected to affect maternal mood or mother-infant interaction. As of February 29, 2016, 598 women had been screened for eligibility, with 168 enrolled and 96 having completed the entire 12-month follow up. Of the 168 women enrolled in the study by February 29, 2016, 9 women had withdrawn from study follow-up since enrollment.

Baseline data were collected through interviews with study staff and questionnaires administered at the initial prenatal visit between 34 and 37 weeks gestation. Follow up contacts occurred monthly, with phone interviews at 1, 3, 5, 7, 8, 9, 10, and 11 months postpartum, and laboratory visits at 2, 6, and 12 months postpartum.

The analytic sample will consist of approximately 160 women drawn from the MMI study between May 2013 and May 2017. The analytic sample will consist of all study participants followed from the third trimester through 12 months postpartum, with approximately 110 considered high-risk and 50 low-risk for postpartum depression/anxiety at baseline. Because all study participants intended to breastfeed for greater than two months, the breastfeeding duration and exclusivity in this sample was expected to be higher than among typical U.S. samples of postpartum women.

Aim 1 Measurement and Methods

Exposure: Experiences of positive emotions during infant feeding

Experiences of positive emotions during infant feeding were assessed at 2, 6, and 12 months postpartum using the mDES. The mDES asked mothers to rate the "greatest amount" they experienced 20 positive and negative emotions during infant feeding over the past seven days using a 5-point scale (0 = not at all, 4 = extremely). Mothers were asked to report these peak emotional experiences based on evidence that recall for salient experiences is more accurate than for averages drawn across several experiences (Fredrickson & Kahneman, 1993; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). The mDES was adapted from Izard's 1977 Differential Emotions Scale, which assesses experiences of 10 discrete emotions (Izard, 1977). The mDES includes two subscales: the positive emotions subscale comprising 10 emotions (amusement, awe, contentment, gratitude, hope, joy, interest, love, pride, and inspiration); and the negative emotions subscale comprising 10 emotions (anger, contempt, disgust, embarrassment, fear, guilt, sadness, hate, stress, and shame). These scales have a high internal reliability ranging from 0.82 to 0.94 (Cohn, Fredrickson, Brown, Mikels, & Conway, 2009; Fredrickson et al., 2008).

The experience of positive emotions during infant feeding at two months will serve as the primary exposure in order to isolate emotions experienced during breast or bottle-feeding of human milk or formula, since by 6 and 12 months many infants will be eating solid foods. This positive emotions score ranges from 0-4 and will be used as a continuous variable to explore the association between a one-point increase in positive emotions and subsequent depression/anxiety symptoms. This continuous measure will be compared for consistency with alternate categorizations, such as binary (at the mean, median, and cutpoints between 2-3), tertiles,

quartiles, and splines, based on the distributions observed in the data. We will use a priori criteria of model fit, using Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC), to select the appropriate functional form of the positive emotions exposure. We will also control for mean negative emotion score at two months to highlight the unique contribution of positive emotions (A. B. Burns et al., 2008; Cohn et al., 2009; Waugh & Fredrickson, 2006).

Outcomes: Postpartum depression and anxiety symptoms

We will consider as primary outcomes the Beck Depression Inventory (BDI-II) scores for depression (A. T. Beck, Steer, & Brown, 1996) and the state inventory scores from the Spielberger State-Trait Anxiety Inventory (STAI-S) for anxiety (Spielberger, 1983), each measured at 2, 6, and 12 months. The BDI-II is a 21-item scale constructed to measure the severity of self-reported depression in adolescents and adults based upon the DSM-IV criteria for depression (A. T. Beck, Steer, Ball, & Ranieri, 1996). Across psychiatric and non-psychiatric samples the BDI-II has a mean reliability α=0.87 and validity of $\alpha \geq$0.60 (A. T. Beck, Steer, & Carbin, 1988) with a good validity and reliability in postpartum women (Ji et al., 2011; Vieira Da Silva Magalhães, Tavares Pinheiro, Lessa Horta, Amaral Tavares Pinheiro, & Azevedo Da Silva, 2008). The STAI-S subscale asks women to rate experiences of 20 feelings "at this moment," such as "I am tense" or "I feel indecisive," using a Likert scale ranging from "not at all" to "very much so." This subscale has been validated in perinatal populations with an internal consistency of 0.91-0.95 (Meades & Ayers, 2011). Scores for the BDI-II range from 0 to 63 (A. T. Beck, Steer, & Brown, 1996) and scores for the state inventory of the STAI-S range from 20 to 80 (Spielberger, 1983).

BDI-II depression scores and STAI-S anxiety scores from 2, 6, and 12 months will be used as continuous outcomes in analyses. We will also explore change scores in BDI-II and

STAI-S between 2-6 and 6-12 months postpartum and analyze outcomes for clinically significant depression threshold scores (BDI-II≥14) and anxiety (STAI-S>40). While this statistical approach remains robust to slightly nonnormal distributions, if outcome variables are extremely nonnormal, skewed toward lower depression/anxiety scores, they will be log transformed or categorized for analysis.

Covariates

Based on the DAG presented in Appendix Figure 2.1.1, the following potential confounders and effect measure modifiers were identified for analysis in Aim 1:

Psychiatric variables

Women's baseline risk status for developing postpartum depression and anxiety symptoms was determined using a full psychiatric SCID Axis I Disorders (First, Spitzer, Gibbon, & Williams, 2002) at the prenatal visit between 34-37 weeks of gestation. Women were categorized as low-risk, based on no symptoms or history of depression or anxiety, or high-risk, based on a SCID-confirmed history or current diagnosis of depression or anxiety. We will explore modification of the exposure-outcome relationship by baseline risk status as well as by presence versus absence of a SCID-confirmed diagnosis of depression or anxiety in pregnancy. We will also control for baseline depression (BDI-II) or anxiety (STAI-S) symptoms assessed in the third trimester of pregnancy.

Current psychiatric medications were self-reported by women at every laboratory visit and phone interview beginning with the prenatal visit and continuing monthly between 1-12 months postpartum. This variable will be dichotomized (Yes/No) for analyses, where a yes will be considered a positive response for treatment. We will use this variable measured between

baseline and two months to control for any treatment occurring before the two-month exposure that might confound its association with depression and anxiety outcomes.

Psychosocial variables

Parenting stress was assessed at 2, 6, and 12 months postpartum using the Parenting Stress Index-Short Form (Abidin, 1995), a 36-item questionnaire asking parents to rate perceived levels of parenting stress on a 4-point Likert scale. Several studies have shown an association between parenting stress and postpartum depression (Cornish et al., 2006; Thomason et al., 2014). This questionnaire provides three subscales of parenting stress: 1) parental distress, which measures feelings of parental competence; 2) difficult child, which measures parental perceptions about the child; and 3) parent-child dysfunctional interaction, which measures the parent's feelings about interacting with the child (Abidin, 1995). The correlation between these subscale scores will be compared with one another and the total score and crude associations with the outcomes will be estimated. Additionally, the correlation between the difficult child subscore and the infant temperament score (see below) will be compared. If these subscores are highly correlated and generally associated with similar estimates of effect on depression and anxiety, the total score from two months will be considered a potential confounder in our analyses. If the subscores are not highly correlated and are differentially predictive of depression and anxiety outcomes, then independent subscores from two months will each be examined as potential confounders in model building.

Adult relationship style was explored at 34-37 weeks gestation using the Experience in Close Relationship Scale-Short Form (ECR-S) (Wei, Russell, Mallinckrodt, & Vogel, 2007), which uses 12 items to assess attachment styles in romantic relationships with respect to six anxiety and six avoidance dimensions (Ainsworth, Blehar, Waters, & Wall, 2014). Respondents

use a 7-point Likert scale to rate the extent to which each item corresponds to their experiences in close relationships. High anxiety and avoidance scores indicate insecurely attached relationship style, while low scores on these dimensions indicate securely attached relationship style. We will use these two continuous variables to control for experiences in close relationships that could affect both emotions during feeding and postpartum mental health (Meuti et al., 2015; Wenzel et al., 2005).

Trauma history was evaluated at 12 months postpartum using the Childhood Trauma Questionnaire (CTQ) (Bernstein et al., 2003). The CTQ is a validated 28-item instrument that uses self-report to identify previous physical, emotional, and sexual abuse and emotional and physical neglect (Bernstein et al., 2003). While measured at 12 months, the childhood trauma score is a potential confounder as it reflects trauma occurring well before both exposure and outcome (Sørbø, Lukasse, Brantsæter, & Grimstad, 2015). We will use a dichotomous (Yes/No) classification for having experienced trauma based on falling above or below a threshold for moderate-to-severe abuse (physical≥10; emotional≥13; sexual≥8) or neglect (physical≥10; emotional≥15) (Bernstein & Fink, 1998).

Antenatal attachment was assessed at the prenatal visit using the Maternal Antenatal Attachment Scale (MAAS) (Condon, 1993). This scale includes 19 items that examine five maternal dispositions toward the fetus: to know, to be with, to avoid separation or loss, to protect, and to gratify needs. It has proved reliable in previous studies with $\alpha = 0.83$ (Condon, 1993) and has been shown to be associated with maternal characteristics like attachment style, relationship quality with one's partner, and parenting stress (Mazzeschi, Pazzagli, Radi, Raspa, & Buratta, 2015). In our preliminary data, antenatal attachment was found to be associated with

more positive emotions during feeding at two months (Stuebe, 2015). This time invariant potential confounder will be treated as a continuous variable.

Infant temperament was measured using the Carey Early Infancy Temperament Questionnaire (EITQ) at 2 months postpartum. This 76-item questionnaire assesses temperament characteristics through parental report with a reliability $\alpha = 0.62$ (Medoff-Cooper, Carey, & McDevitt, 1993). A higher score indicates more difficult/less desirable infant characteristics, while a lower score indicates easy/more desirable characteristics. This questionnaire includes nine subscales of infant temperament; the same process described for parenting stress above will be used to analyze whether subscale mean scores or the total mean score will be used as a covariate, given the association between difficult infant temperament and postpartum depression (Cutrona & Troutman, 1986).

Social support was evaluated at the prenatal visit and 2, 6, and 12 months postpartum using the Medical Outcomes Study Social Support Survey (MOS) (Sherbourne & Stewart, 1991). This 19-item survey evaluates the size of the woman's network in addition to four dimensions of support: emotional/informational support, affectionate support, tangible support and social interaction (Sherbourne & Stewart, 1991). We will use the same process described for parenting stress to analyze whether subscores or the total score will be used to control for baseline levels of social support that could influence both exposure and outcome.

The Coping Strategies Questionnaire (Rosenstiel & Keefe, 1983) was used at baseline to assess the mother's self-reported ability to cope with pain.

Pregnancy and Lactation variables

Birth trauma was assessed via the modified perinatal post-traumatic stress disorder questionnaire (Callahan, Borja, & Hynan, 2006).

Breastfeeding problems could confound the association between emotions during feeding and depression/anxiety outcomes. A continuous score will be created by totaling the number of problems women reported for the first two weeks of breastfeeding, from 0 for "I had no problems" to 18 for each of the problems listed, including "I had some other problem."

Breast pain during breastfeeding on the first day, first week, and second week postpartum were assessed at the month one phone interview. Mothers reported the amount of breast pain experienced using a Likert scale (0=None, 4=Severe).

"Met breastfeeding intention" will be constructed based on women's achieving or not achieving their prenatal breastfeeding intention at two months. Intention will be defined using responses to the following two questions asked at 34-37 weeks: "How old do you think your baby will be in months when you first feed him or her formula or any other food besides breast milk?" and "How old do you think your baby will be when you completely stop breastfeeding?" This variable will be dichotomized (Yes/No) for analyses, where a yes indicates that the mother has met both intentions at two months.

Pregnancy intention was determined at the prenatal visit using a six-item measure of "circumstances of pregnancy" that has been shown to have high reliability ($\alpha = 0.92$) (Barrett, Smith, & Wellings, 2004) and high validity in a U.S. population (Morof et al., 2012). The total score from this six-item measure will be used to quantify pregnancy intention.

Demographic variables

Maternal race/ethnicity, marital status, income, and education were reported at the baseline prenatal visit. The timing of a mother's postpartum return to work was determined through a questionnaire administered monthly between 1-12 months postpartum. Women were asked the following: "Did you begin working for pay or going to school since the last interview

or study visit? If yes, how old was your baby when you began working/attending school after your delivery?" We will use a dichotomous (Yes/No) variable based on women's self-report at months one and two to control for this potential confounder.

Aim 1 Analyses

Univariate distributions, including proportions, means, and graphical summaries to examine skew, kurtosis, and outliers will be assessed for each of the variables presented above. Bivariate associations between key covariates and depression and anxiety symptoms will be examined. The relationship between continuous variables and outcomes will be assessed for linearity, and alternate coding schemes will be considered if necessary for improved model fit and interpretation. If underpowered to include all covariates from the minimally sufficient adjustment set, we will remove covariates with the weakest associations to the exposure and outcome and use variables from the same covariate category to represent the construct. We expect the amount of missing data to be trivial based on preliminary data; however, if any key covariate has a substantial proportion of missing data (>5%), the covariate will be dropped if another variable from its covariate category can adequately characterize the construct; if not, multiple imputation will be used.

We hypothesize that, on average, women with higher positive emotions during infant feeding at two months postpartum will have lower postpartum depression/anxiety symptoms between months two and 12 postpartum compared with women who report lower positive emotions. We will conduct an exploratory data analysis by plotting individual outcome measures, fitting a smoothing spline over time, and exploring subgroup differences by baseline psychopathology. Multivariable generalized linear mixed models will be used to estimate the crude and multivariable associations between experiences of positive emotions during infant

feeding at two months and depression/anxiety scores at 2, 6, and 12 months postpartum. The experience of positive emotions during infant feeding at two months will be analyzed as a continuous exposure and compared for consistency with alternate categorizations based on the distributions observed in the data that may lead us to collapse categories or separate dissimilar groups. Influential or extreme outliers will be examined and will be removed if the full model estimate changes >20% with the removal of influential outliers.

Generalized linear mixed models will be used to estimate crude and multivariable associations between positive emotions at two months and depression outcomes at 2, 6, and 12 months. To account for intraperson correlations across repeat measures, correlations among data drawn from points closer in time, and differences in variance over time, covariance structures that allow for unequally spaced outcomes (at 2, 6, and 12 months postpartum) will be compared for best model fit. Both a random intercept to allow baseline depression/anxiety scores to differ among participants and a random effect for time to account for interperson differences in the rate of change will be included in model building. The relationship between positive emotions and depression/anxiety symptoms will be explored using linear, quadratic, and spline transformations to best describe the trend over time. Covariates will be added to the model as fixed effects.

Effect measure modification will be examined by high versus low baseline risk status for postpartum depression/anxiety and by presence or absence of a SCID-confirmed diagnosis of depression or anxiety at baseline, given the increased risk of postpartum depression/anxiety associated with both prenatal and pre-pregnancy psychopathology. Effect measure modification will be assessed using stratification as well as interaction on the multiplicative scale. For baseline psychopathology to be included as an effect measure modifier, there must be LRT p-values <0.05 when comparing the exposure-outcome relationship with and without the interaction term.

To evaluate and adjust for confounding, estimates from fully adjusted models with the sufficient adjustment set of covariates described above will be compared to estimates from reduced models. For a covariate to be included as a confounder, it must a) result in a change the exposure-outcome effect estimate by >10% using backward elimination from the full model and b) be considered to address residual confounding in the literature as represented in the DAG. To avoid over-adjustment, we will explore collinearity using a scatterplot matrix and correlation table for all covariates, considering variables with a p-value <0.0001 and a Pearson Correlation Coefficient >0.5 to be potentially problematic and removing any variables that cause model instability when included in the full model. All analyses will be performed using SAS 9.4.

Sensitivity and Secondary Analyses:

We will conduct two planned sensitvity analyses. 1) First, we will exclude women taking psychiatric medications, as their BDI-II and STAI-S scores may be low due to treatment for their depression or anxiety despite their elevated baseline risk. 2) We will exclude women who are exclusively formula feeding at two months, as these women may be categorically different from mothers able to continue some amount of breastfeeding in a sample of women who at baseline desired to breastfeed at least two months.

Secondary analyses will explore modification of the association between experiences of positive emotions during feeding and depression/anxiety outcomes by negative emotions during feeding score, infant temperament score, number of early breastfeeding problems, meeting one's breastfeeding intention by two months, and history of moderate/severe childhood trauma.

Aim 2 Measurement and Methods

Exposure: Experiences of positive emotions during infant feeding (See Aim 1)

Outcomes: Any and exclusive breast milk feeing cessation between months 3-12 and overall maternal evaluation of breastfeeding at 12 months

Every month between 1 and 12 months postpartum, mothers were asked about how many times on average over the previous week the infant was fed breast milk (whether at-breast, expressed or donor human milk), formula, or solid foods. Time to cessation of any breast milk feeding will be defined using the infant age in weeks from birth to the date of the visit when the mother reports no longer feeding any breast milk in the previous week (or the final visit for censored observations). Women who are exclusively formula feeding at two months will be excluded from the analysis, as they cannot contribute any time to event data. Based on preliminary data, we expect approximately 90-95% of the original sample to remain in the analytic sample after excluding women formula feeding at 2 months. Time to cessation of exclusive breast milk feeding will be defined using the infant age in weeks from birth to the date of the visit when the mother reports feeding anything other than breast milk in the previous week (or the six-month visit for censored observations).

Women's overall experience of breastfeeding was estimated using the Maternal Breastfeeding Evaluation Scale (MBFES) at 12 months postpartum. The MBFES asks women to consider their overall experience of breastfeeding and/or expressing milk for their most recent baby, comprising 30 items such as "It was a burden being my baby's main source of food" and "My baby and I worked together to make breastfeeding go smoothly" (Leff, Jefferis, & Gagne, 1994). Women responded using a 5-point Likert scale (1="strongly disagree," to 5="strongly

agree"). This tool has been shown to have a high reliability with a Cronbach's alpha of 0.93 (Leff, Jefferis, et al., 1994). For this analysis, the total MBFES score will be considered the primary outcome, using a continuous variable where a higher score indicates higher satisfaction. Subscores are generated for the following three dimensions of maternal breastfeeding experiences: maternal enjoyment/role attainment, infant satisfaction/growth, and lifestyle/maternal body image (Leff, Jefferis, et al., 1994). These three subscores will be considered as secondary outcomes, using continuous variables where higher scores indicate higher satisfaction.

Covariates

Based on the available sample of approximately 110 women, Aim 2 models can support approximately 11 variables. Based on the DAG presented in Appendix Figure 3.1.1, the same potential covariates identified in Aim 1 will be considered for analysis in Aim 2 (see Aim 1 Covariates for more information on variable construction and timing of data collection):

Aim 2 Analyses

The same exploratory analysis process will be used as described in Aim 1 Analyses (see above). We hypothesize that women with higher positive emotions during infant feeding at two months postpartum will sustain longer time to any and exclusive breast milk feeding cessation and will have a better overall experience of breastfeeding at 12 months compared to women with lower positive emotions. Cox proportional hazards regression models will be used to estimate hazard ratios for time to any and exclusive breast milk feeding cessation associated with a one-point increase in positive emotions.

The experience of positive emotions during infant feeding at two months will be analyzed as a continuous exposure and compared for consistency with the classification of the exposure as

a dichotomous exposure. Alternate categorizations of the exposure, such as the tertiles, quartiles, and binary classifications (at the mean, median, and cutpoints between 2 and 3) will also be explored based on the distributions observed in the data that may lead us to collapse categories or separate dissimilar groups. Influential or extreme outliers will be examined and will be removed if the full model estimate changes >20% with the removal of influential outliers. The same process as described in Aim 1 will be used to explore effect measure modification by women's baseline psychopathology. Confounders were included where they were identified as important to adjust for based on subject-matter knowledge as represented in the DAG (Dagitty, version 2.3) and removed if collinearity with other variables caused model instability indexed by inflated estimates or standard errors.

Linear regression will be used to estimate the crude and multivariable associations between experiences of positive emotions during infant feeding at two months and the total score of global breastfeeding experience at 12 months. Effect measure modification will be explored by baseline psychopathology. For a covariate to be included as a confounder in linear models, it must a) result in a change the exposure-outcome effect estimate by >10% using backward elimination from the full model and b) be considered to address residual confounding in the literature as represented in the DAG.

Sensitivity and Secondary Analyses

Sensitivity analyses will be conducted using a measure of maternal feelings about breastfeeding in the first week postpartum. This exposure measure was defined by asking women how they felt about breastfeeding during the first week postpartum using a Likert scale (1=Disliked very much, 5=Liked very much). While this measure does not assess positive emotions using a well-validated tool, sensitivity analyses using this exposure address potential

selection bias in the main analyses resulting from immortal person time. Immortal person time occurs because the mDES exposure was first measured at two months postpartum, thereby excluding from analyses those women who stopped any or exclusive breast milk feeding before that time. By repeating analyes with a measure of maternal feelings about breastfeeding in the first week postpartum, we retained the entire sample to determine if results differed due to selection bias.

Secondary analyses will explore modification of the association between positive emotions and breastfeeding outcomes by moderate/severe childhood trauma, having met one's prenatal breastfeeding intention, and breast milk feeding status at the time of exposure assessment. Finally, we will conduct an additional sensitivity analysis excluding women taking psychotropic medications, since their emotional experience and duration of infant feeding may be systematically different from women not taking these medications.

Potential Limitations

Unmeasured confounding is likely limited due to breadth of data collected on participants from the third trimester of pregnancy through 12 months postpartum. However, self-report measures used in analyses may contribute to reporting bias due to under- or over-reporting. While a diagnostic interview was used at baseline to assign women to risk categories for postpartum depression/anxiety, we use self-report measures of positive emotions during feeding, postpartum depression/anxiety symptoms, and breastfeeding practices. However, BDI-II and STAI-S anxiety tools have been validated in postpartum populations (Meades & Ayers, 2011; Vieira Da Silva Magalhães et al., 2008), and maternal recall of breastfeeding practice has been shown to be valid and reliable, especially when recalled after only a short period (Li, Scanlon, &

Serdula, 2005). In our study, infant feeding practices were recalled over the previous week to improve accuracy.

The mDES has not previously been applied in a postpartum context nor has it been used specifically to explore emotions experienced during infant feeding. However, this tool has been used in numerous interventions across a variety of contexts asking respondents to rate emotions over the past 24 hours (Cohn et al., 2009; Fredrickson et al., 2008; Kok & Fredrickson, 2010), the past two weeks (Hogan et al., 2015; Johnson et al., 2011; Waugh & Fredrickson, 2006), or over extended periods of time (Fredrickson, Tugade, Waugh, & Larkin, 2003). While the mDES was first asked at two months postpartum, after many breastfeeding problems may have been addressed, we do explore confounding by early breastfeeding problems in the analyses and conduct sensitivity analyses in Aim 2 using a measure of maternal feelings about breastfeeding in the first week postpartum. Additionally, the MBFES was only asked at 12 months, so we are limited to understanding women's overall experience of breastfeeding only after the first postpartum year.

Due to the small total sample size and proportion of participants who are women of color or of low SES, we will be underpowered to estiamate associations between positive emotions and outcomes within racial/ethnic or SES categories. Such analyses would be of interest in future studies given well-established associations between social determinants of health and both infant feeding and mental health.

In order to enroll in the study, women must have intended to breastfeed for at least two months; these women are likely to be more highly motivated to breastfeed than the general population. Moreover, women with severe depression or anxiety symptoms may have been

unwilling to enroll in an intensive year-old study. Both of these factors limit the generalizability of results to similar populations.

As with any observational data, we are not able to determine causal effects between positive emotions during infant feeding and mood or breastfeeding outcomes. For Aim 1, depression and anxiety outcomes are measured concurrently with the exposure only at two months, and we assume that the experiences of positive emotions at two months affects subsequent depression and anxiety scores. We will repeat analyses using only 6- and 12-month outcomes to support this assumption. For Aim 2, temporality between the exposure and outcome is preserved as all breast milk feeding outcome data were collected monthly following the two-month exposure. Despite the use of longitudinal data to support the temporality of our hypothesized associations, the potential bi-directionality of the relationship between positive emotions and both depression/anxiety as well as breastfeeding outcomes remains.

Finally, there is potential for a floor and ceiling effect to limit the variation in the outcome estimates of our study sample. Among women considered low-risk for postpartum depression or anxiety at baseline, there may be many women with consistently low BDI-II and STAI-S scores across the study follow-up. Additionally, there may be consistently high any and exclusive breast milk feeding rates among participants who are highly motivated to breastfeed.

Sample and Power

The main outcome measures include depression/anxiety scores for Aim 1 and time to any and exclusive breast milk feeding cessation for Aim 2.

For Aim 1, statistical power was calculated using PROC POWER in SAS 9.4 (SAS Institute, Cary, NC). A Type I error probability of 5%, with a two tailed test, was used in calculations. To account for repeated measures on study participants over time, the total expected

sample size used in power calculates was adjusted for clustering. The effective sample size (ESS) for clustered samples was calculated using the following equation:

$$ESS = (m * k)/DE$$

where m refers to the number of observations per cluster, k is the number of clusters (or participants), and DE is the design effect (a correction factor applied that takes into account the correlation between observations within a cluster). DE is calculated using the following equation:

$$DE = 1 + ((m - 1) * \rho)$$

where ρ is the intracluster correlation coefficient, which can vary from 0 to 1 (Killip, Mabfoud, & Pearce, 2004). The number of participants, k, is expected to be 120 for Aim 1. The average number of observations per participant, m, is assumed to be 3. Allowing ρ to vary between 0.5 and 0.9, assuming a moderate to high correlation of depression scores within individuals, the for depression Aim 1 is expected to range between 129-180.

For depression scores, we calculated the power to detect a mean change of 3-5 points based on two studies: 1) a positive psychology intervention study delivered to women with mild to moderate depressive symptoms that showed a change in BDI scores between intervention and control groups of approximately 4.88 points, with a standard deviation of approximately 6.3 (Seligman et al., 2006); and 2) an observational study that followed women from pregnancy to the early postpartum that found a difference of approximately 3.33 on the BDI-II at one week postpartum comparing women who experienced a high degree of positive emotions during pregnancy versus a moderate degree of positive emotions, with a pooled standard deviation of 4.03 (Moraitou et al., 2011). The power to detect a mean difference in depression scores between

3-5 with a conservative pooled standard deviation of 6 yields effective sample sizes of 129, 150, and 180. Even under the worst-case scenario of an ESS of 129, we expect >80% power to detect a 3-5 point change in depression scores.

For anxiety scores, we calculated the power to detect a mean change of 5-7 based on the limited available literature. Across 2 psychosocial or relaxation interventions delivered to women during pregnancy or the early postpartum, mean change in STAI state anxiety scores ranged from 5 to 7.25 (Teixeira, Martin, Prendiville, & Glover, 2005; Vieten & Astin, 2008). The power to detect a mean difference in anxiety scores between 5-7 with a pooled standard deviation of 7.55 yields effective sample sizes of 129, 150, and 180. Even under the worst-case scenario of an ESS of 129, we expect >80% power to detect a 5-7 point change in anxiety scores.

For Aim 2, we calculated the sample size needed for Cox proportional hazards regression models with nonbinary covariates (Hsieh & Lavori, 2000). Based on preliminary data, we expected a probability of failure (i.e. of breast milk feeding cessation) of approximately 35% for any breast milk feeding by 12 months and 75% for exclusive breast milk feeding by 6 months. We estimated the variance of our continuous exposure measure based on published studies indicating the standard deviation at any given time point for the mDES is about 0.60 (Fredrickson et al., 2008; Kok et al., 2013). We used the stpower command in StataSE (version 15) to estimate the sample size and number of events needed to achieve 80% power with a two-sided alpha of 0.05.

We estimated that approximately 130 subjects and 40 events will be needed to detect a significant difference in the hazard of stopping any breast milk feeding by 12 months associated with a continuous measure of positive emotions. For our exclusive breast milk feeding outcome,

we estimated that approximately 61 subjects and 46 events would be needed to detect a significant difference in the hazard of stopping exclusive breast milk feeding by six months.

The power of moderator analyses depends on the distribution of participant characteristics and variability in positive emotions and mental health and breastfeeding outcomes observed, which cannot be estimated reliably at this time.

CHAPTER 2 - POSITIVE EMOTIONS DURING INFANT FEEDING AND MATERNAL MENTAL HEALTH

Overview

Background: Research shows that individuals can improve mental health by increasing experiences of positive emotions. However, the role of positive emotions in perinatal mental health has not been investigated. This study explored the extent to which positive emotions during infant feeding are associated with maternal depression and anxiety across the first year postpartum.

Methods: 164 women drawn from a longitudinal cohort of mother-infant dyads were followed from the third trimester through 12 months postpartum. We measured positive emotions during infant feeding at two months using the mean subscale score of the modified Differential Emotions Scale. Depression and anxiety symptoms were assessed using the Beck Depression Inventory-II and State Trait Anxiety Inventory-State subscale at months 2, 6, and 12. Generalized linear mixed models were used to estimate crude and multivariable associations.

Results: Among women with no clinical depression during pregnancy, higher positive emotions during infant feeding at two months were associated with significantly fewer depression symptoms at 2, 6, and 12 months and with lower odds of clinically significant depression symptoms at 2 and 6 months. In contrast to depression outcomes, women with clinical anxiety in pregnancy who experienced higher positive emotions had significantly fewer anxiety symptoms at 2, 6, and 12 months and lower odds of clinically significant anxiety at six months.

Conclusions: Positive emotions during infant feeding are associated with depression and anxiety outcomes across the first year postpartum and may be a modifiable protective factor for maternal mental health.

Background

Perinatal depression and anxiety are two of the most common complications of childbirth (O'Hara & Swain, 1996; Sockol et al., 2011), and they are associated with adverse outcomes for both mother and infant (Grote et al., 2010; Kingston & Tough, 2013; Paul et al., 2013). Despite their prevalence and morbidity, perinatal depression and anxiety are under-diagnosed and under-treated, with less than 50% of symptomatic women receiving a diagnosis (Goodman & Tyer-viola, 2010; Ko et al., 2012) or seeking treatment (Vesga-Lopez & Blanco, 2008). Among those who do seek treatment, many pregnant and breastfeeding women prefer non-pharmacologic options due to concerns about infant exposure to psychotropic medications (Battle et al., 2013; Sockol et al., 2011). To reduce morbidity for mothers and infants, novel strategies are needed to prevent and treat perinatal depression and anxiety.

One promising target for intervention is positive emotionality. Positive emotions are pleasantly-valenced discrete responses to one's appraisal of circumstances as favorable, (Fredrickson, 2013) with biobehavioral features that are empirically distinguishable from negative emotions (Garland et al., 2010). Positive psychology interventions that increase experiences of positive emotions have been shown to experimentally reduce depression and anxiety symptoms (David J Kearney, Martinez, Kearney, Mcmanus, & Malte, 2014; Seligman et al., 2006; Taylor et al., 2016) and to improve resilience to future stressors through resources such as social support (Fredrickson et al., 2008) and coping skills (A. B. Burns et al., 2008; Fredrickson & Joiner, 2002). The broaden-and-build theory of positive emotions (Fredrickson,

2004) posits that these durable psychological and social resources result from the broadened cognitive and creative context associated with experiences of positive emotions (Isen et al., 1985; Subramaniam & Vinogradov, 2013).

Preliminary evidence suggests an association between positive emotions and postpartum mental health. Among 344 Norwegian mothers followed across six months postpartum, those using positive reappraisal as a coping strategy reported fewer depression symptoms (Haga et al., 2012). An observational study of 195 Greek women found an inverse association between positive emotions in the third trimester and depression symptoms at one week postpartum (Moraitou et al., 2011). However, neither of the above studies controlled for women's baseline mental health status, calling the causal direction of this association into question. In a sample of breastfeeding mothers, those with fewer postpartum depression and anxiety symptoms reported higher positive affect during observed feeding sessions at two and eight weeks (Stuebe et al., 2013a). Positive emotions experienced during regular mother-infant interactions such as infant feeding may broaden their associated benefits by increasing maternal sensitivity and attachment (E. Burns et al., 2010; Kok et al., 2013). Mothers who describe breastfeeding as a positive activity express feeling connected to their infant, self-confident as a parent, and supported to face new challenges (E. Burns et al., 2010). To our knowledge, no study has explored the association between positive emotions experienced during infant feeding and prospective maternal mental health outcomes.

To better understand the role of positive emotions in perinatal mental health, we estimated the association between positive emotions during infant feeding and maternal depression and anxiety symptoms across the first year postpartum. Grounded in the broaden-and-build theory, we hypothesized that women reporting more positive emotions during infant

feeding at two months would have fewer postpartum depression and anxiety symptoms at 2, 6, and 12 months. We also explored the extent to which associations between positive emotions and depression and anxiety symptoms differed by women's baseline psychopathology.

Methods

Sample

Our sample was drawn from 220 pregnant women enrolled in the longitudinal cohort study *Mood, Mother and Infant: The Psychobiology of Impaired Dyadic Development* (MMI) and followed from the third trimester until 12 months postpartum. The MMI cohort comprised women living near Chapel Hill, North Carolina, recruited from study fliers and obstetric or psychiatric visits. We oversampled women at elevated risk for postpartum depression and anxiety based on a history of depression/anxiety or an active depressive/anxiety disorder in the third trimester of pregnancy using a Structured Clinical Interview for DSM-IV (SCID). By design, about 1/3 of women had an active depression or anxiety disorder in pregnancy, 1/3 had a history, and 1/3 had no history. Eligible participants were 18-45 years old, enrolled at 34-37 weeks' gestation of a singleton pregnancy, able to communicate in English, and intending to breastfeed more than two months. Women were excluded from the study if they met any of the following criteria: history or current diagnosis of psychiatric disorders other than depression/anxiety; substance use disorder; NICU admission >48 hours, major congenital anomaly, or neonatal death; use of tricyclic antidepressants; or contraindication for breastfeeding. A full description of the study can be found at http://mmi.web.unc.edu.

For this analysis, we restricted to participants completing their 12-month visit by May 2017 (n=177). We excluded women missing exposure data (n=12) and one influential outlier based upon a priori criteria. The remaining 164 women comprise our analytic sample.

Measures

Baseline data were collected through questionnaires and interviews with study staff at the third trimester laboratory visit, and follow-up contacts occurred through monthly phone interviews and laboratory visits at 2, 6, and 12 months postpartum.

Positive Emotions during Infant Feeding

At two months postpartum, participants completed the modified Differential Emotions Scale (mDES) (Fredrickson et al., 2003), rating the "greatest amount" they experienced 20 positive and negative emotions during infant feeding over the past week using a 5-point Likert scale (0=not at all, 4=extremely). The mDES was adapted from Izard's Differential Emotions Scale (Izard, 1977) and has a high internal reliability ranging from 0.82-0.94 (Cohn et al., 2009; Fredrickson et al., 2008). Our exposure uses the positive emotions subscale of the mDES, which provides a mean score across 10 discrete emotions: amusement, awe, contentment, gratitude, hope, joy, interest, love, pride, and inspiration. Because this is the first time the mDES is applied in the context of infant feeding, we conducted a confirmatory factor analysis that indicated the 10 positive emotions best correlate with a single factor with roughly equal factor loadings for all items (CFI=0.9530) (see Appendix Figure 1.1.1).

The experience of positive emotions during infant feeding at two months was analyzed as a continuous exposure and compared for consistency with alternate categorizations, such as binary (at the mean, median, and cutpoints between 2-3), tertiles, quartiles, and splines, based on the distributions observed in the data. Using a priori criteria of model fit, we chose a continuous exposure for all analyses to estimate outcomes associated with one-point increases in positive emotions. We present descriptive characteristics by high (>2.5) versus low (<=2.5) positive emotions during infant feeding, which had the second most optimal model fit.

Postpartum Depression and Anxiety Symptoms

At 2, 6, and 12 months, depression symptoms were measured using the Beck Depression Inventory (BDI-II) (A. T. Beck, Steer, & Brown, 1996), and anxiety symptoms were measured using the State Trait Anxiety Inventory-State (STAI-S) subscale (Spielberger, 1983). Both instruments have been validated in perinatal populations (Meades & Ayers, 2011; Vieira Da Silva Magalhães et al., 2008). Outcomes were assessed as both continuous symptoms and binary thresholds for meeting clinically significant cutoffs for depression or anxiety. A BDI-II cutoff of ≥14 has been shown to have a 92% sensitivity and 83% specificity for major depression based on a Mini International Neuropsychiatric Interview in a postpartum outpatient sample (Wang & Gorenstein, 2013), and a STAI-S>40 administered at one week postpartum had a 67.5% sensitivity and 87.1% specificity in identifying anxious mothers using the STAI-S at eight weeks (Dennis, Coghlan, & Vigod, 2013).

Potential Covariates

We used a DAG (Greenland, Pearl, & Robins, 1999) to identify potential confounding and effect measure modification (see Appendix Figure 2.1.1). Potential confounding variables were indexed as follows: Baseline depression and state anxiety symptoms were quantified using BDI-II and STAI-S scores. Moderate/severe childhood trauma was defined as abuse (physical ≥10; emotional ≥13; sexual≥8) or neglect (physical ≥10; emotional ≥15) (Bernstein et al., 2003) via Childhood Trauma Questionnaire. The number of early breastfeeding problems and amount of breast pain during breastfeeding via Likert scale (0=none, 4=severe) were reported at the month one phone interview (Centers for Disease Control and Prevention, 2014). Return to work by two months was based on self-report at months one and two. Infant temperament was assessed via Carey Early Infancy Temperament Questionnaire (Medoff-Cooper et al., 1993) and

social support via the Medical Outcomes Study Social Support Survey (Sherbourne & Stewart, 1991). Meeting one's prenatal breastfeeding intention by two months was defined as meeting baseline duration and exclusivity intentions at month two. Concurrent negative emotions during infant feeding were defined via mDES at month two to highlight the unique contribution of positive emotions beyond the presence or absence of negative emotions (A. B. Burns et al., 2008; Waugh & Fredrickson, 2006). We also explored modification of the association between positive emotions and postpartum depression/anxiety by women's baseline psychopathology: we tested for modification by the presence or absence of clinical depression/anxiety during pregnancy via third trimester SCID and by risk status for postpartum depression/anxiety, where "high risk" was indexed by a SCID-confirmed history of depression/anxiety or an active depressive/anxiety disorder in pregnancy.

Statistical analyses

Generalized linear mixed models were used to estimate the crude and multivariable associations between experiences of positive emotions during infant feeding at two months and depression and anxiety scores at 2, 6, and 12 months. Linear mixed models are appropriate for longitudinal data with correlated error terms and both population-specific parameters (fixed effects) and subject-specific parameters (random effects). Based on Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC), the best-fitting model for continuous outcomes included a random intercept to allow two-month depression/anxiety scores to differ among participants, a random effect for time to account for inter-person differences in linear change in scores over time, and a variance components covariance structure. For binary outcomes, the best-fitting models included a random intercept only.

Confounders were included where they a) were identified as important to adjust for based on subject-matter knowledge as represented in the DAG (Dagitty, version 2.3) and b) resulted in a change in the exposure-outcome effect estimate by >10% using backward elimination from the full model. Crude and adjusted estimates and their associated 95% confidence intervals (CI) are presented for overall models. Effect measure modification was considered to be present where Likelihood Ratio Test (LRT) p-values were <0.05 comparing models with and without an interaction term. Analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

Sensitivity analyses repeated above analyses removing 1) exclusive formula feeders at two months, as these women may have a different emotional experience of infant feeding, and 2) women taking psychotropic medications for their depression or anxiety, as their symptoms may be low due to treatment despite their elevated baseline risk (see Appendix 2.1 for additional analyses).

Results

Study sample characteristics

Descriptive characteristics are presented for the 164 women in the study sample by high (>2.5 to 4) versus low (0 to 2.5) positive emotions scores (see Table 2.1 below). The mean positive emotions score was 2.8 (SD=0.8), with about 65% of the sample classified as experiencing high positive emotions. Based on the third trimester SCID, 36% of the sample was defined as low risk for postpartum depression/anxiety, 31.1% was defined as "high risk" due to a history of a depressive/anxiety disorder, and 32.9% as "high risk" due to an active depressive/anxiety disorder. Approximately 24% of the sample had an active depressive disorder in pregnancy (Major Depressive Disorder, Dysthymic Disorder, Depressive Disorder NOS, or Postpartum Depression) and about 26% had an anxiety disorder (Panic Disorder, Agoraphobia

without history of Panic, Social Phobia, Obsessive Compulsive Disorder, Post-Traumatic Stress Disorder, or Generalized Anxiety Disorder), with no significant differences by high versus low positive emotions. Approximately 76% of the sample was Non-Hispanic White, almost half reported a post-graduate level of education, and about 90% were married/partnered, with no significant differences in positive emotions by sociodemographic characteristics. Approximately 27% of the sample was taking a psychotropic medication between baseline and exposure. Nearly one third of the sample had not met their prenatal breastfeeding intention for any or exclusive breastfeeding by two months, with a higher percentage of these women reporting low positive emotions. Women with higher positive emotions during infant feeding at two months were significantly more likely to have returned to work by two months, report higher levels of antenatal attachment, and feel more positively about breastfeeding in the first week postpartum. Women with higher positive emotions during feeding were also significantly less likely to experience negative emotions during feeding, a traumatic birth experience, early breastfeeding problems, and parenting stress at two months (Table 2.1).

Table 2.1: Descriptive statistics for Aim 1 sample by low (0-2.5) versus high (>2.5-4) positive emotions

Variable	Overall		Low Positive Emotions[a]		High Positive Emotions[a]		p-value[b]
	Mean (SD) or N	(%)	Mean (SD) or N	(%)	Mean (SD) or N	(%)	
Total	164		58	(35.4)	106	(64.6)	
Positive emotions during infant feeding[a]	2.8 (0.8)		1.9 (0.6)		3.3 (0.4)		**<0.001**
Baseline psychopathology[c]							0.52
Low risk	58	(36.0)	18	(31.0)	41	(38.7)	
High risk, history of depression/anxiety	51	(31.1)	18	(31.0)	33	(31.1)	
High risk, active depression/anxiety disorder in pregnancy	54	(32.9)	22	(37.9)	32	(30.2)	
Baseline depression[c]							0.22
No prenatal depression	125	(76.2)	41	(70.7)	84	(79.2)	
Clinical depression in pregnancy	39	(23.8)	17	(29.3)	22	(20.8)	
Baseline anxiety[c]							0.16
No prenatal anxiety	121	(73.8)	39	(67.2)	82	(77.4)	
Clinical anxiety in pregnancy	43	(26.2)	19	(32.8)	24	(22.6)	
Race/ethnicity							0.45
Non-Hispanic White	125	(76.2)	47	(81.0)	78	(73.6)	
Non-Hispanic Black	15	(9.1)	3	(5.2)	12	(11.3)	
Hispanic, any race	15	(9.1)	4	(6.9)	11	(10.4)	
Other	9	(5.5)	4	(6.9)	5	(4.7)	
Education level							0.14
Some high school or high school grad	10	(6.1)	4	(6.9)	6	(5.7)	
Some college or college grad	80	(48.8)	30	(51.7)	50	(47.2)	
Post-graduate level	74	(45.1)	24	(41.4)	50	(47.2)	
Marital status							0.69
Married/partnered	149	(90.9)	52	(89.7)	97	(91.5)	
Single/divorced	15	(9.1)	6	(10.3)	9	(8.5)	
Parity							0.88
Nulliparous	89	(54.3)	31	(53.4)	58	(54.7)	

Multiparous	75	(45.7)	27	(46.6)	48	(45.3)	
Psychotropic medications between baseline and 2 months[d]							0.07
Yes	45	(27.4)	21	(36.2)	24	(22.6)	
No	118	(72.0)	37	(63.8)	81	(76.4)	
Missing	1	(0.6)	0	0	1	(0.9)	
Met prenatal breastfeeding intention at 2 months[e]							0.43
Yes	108	(66.3)	37	(63.8)	72	(67.9)	
No	53	(32.5)	21	(36.2)	32	(30.2)	
Missing	2	(1.2)	0		2	(1.9)	
Returned to work by 2 months							**0.03**
Yes	49	(29.9)	11	(19.0)	38	(35.8)	
No	113	(68.9)	46	(79.3)	67	(63.2)	
Missing	2	(1.2)	1	(1.7)	1	(0.9)	
Moderate to severe childhood trauma experience[f]							
Yes	41	(25.0)	14	(24.1)	27	(25.5)	0.80
No	121	(73.8)	44	(75.9)	77	(72.6)	
Missing	2	(1.2)	0	0	2	(1.9)	
Negative emotions during infant feeding[a]	0.6 (0.6)		0.7 (0.6)		0.5 (0.5)		**0.01**
Traumatic birth experience[g]	6.0 (6.3)		7.8 (7.0)		5.0 (5.6)		**0.01**
Infant temperament at 2 months[h]	27.6 (3.3)		27.8 (3.5)		27.4 (3.3)		0.44
Antenatal attachment[i]	76.8 (5.9)		74.8 (6.3)		77.9 (5.4)		**0.001**
Social support at 2 months[j]	3.4 (0.6)		3.3 (0.7)		3.5 (0.6)		0.05
Breast pain, day one postpartum[k]	1.2 (0.9)		1.2 (0.9)		0.9 (0.9)		0.12
Breastfeeding problems in first 2 weeks[l]	4.1 (1.9)		4.6 (2.0)		3.8 (1.9)		**0.02**
Positive feelings about breastfeeding in the first week[m]	3.5 (1.4)		3.1 (1.4)		3.8 (1.3)		**0.003**
Parenting stress at 2 months[n]	66.9 (17.3)		77.6 (16.4)		61.6 (15.3)		**<0.001**

[a]mDES scores range from 0 to 4, with higher scores indicating more emotions; descriptive statistics are presented by high positive emotions (score of >2.5-4) and low positive emotions (0-2.5).

[b]Independent samples t-test for continuous variables; chi-square test and fisher's exact test for categorical variables

[c]Active disorder is based on Structured Clinical Interview for Diagnosis (SCID) criteria for active depression (including Major Depressive Disorder, Dysthymic Disorder, Depressive Disorder NOS, or Postpartum Depression); a history of depressive disorder and current treatment with antidepressants or psychotherapy >once per month; active anxiety (including Panic Disorder, Agoraphobia, Social Phobia, Obsessive Compulsive Disorder, Generalized Anxiety Disorder, or Post

Traumatic Stress Disorder); or a history of an anxiety disorder and current treatment with antidepressants, benzodiazepines, or psychotherapy >once per month; high risk with no active disorder is defined via SCID-confirmed pre-pregnancy history of a depressive/anxiety disorder; low risk is defined as no history of or active disorder

[d]Includes self-reported use of the following medications: antidepressants, benzodiazepines, antipsychotics, and hypnotics

[e]Defined as meeting prenatal intention for any and exclusive breastfeeding

[f]Defined as meeting the threshold for moderate/severe emotional abuse, physical abuse, sexual abuse, emotional neglect, or physical neglect on the 28-item Childhood Trauma Questionnaire

[g]Modified Perinatal Post-Traumatic Stress Disorder (ptsd) Questionnaire scores range from 0-56, with higher scores indicating more perinatal ptsd

[h]Carey Early Infancy Temperament Questionnaire (EITQ) comprises 9 categories of temperament, with higher scores indicating more difficult/negative qualities

[i]Maternal Antenatal Attachment Scale scores range from 19-95, with higher scores indicated stronger attachment

[j]Medical Outcomes Study Social Support Survey (MOS) scores range from 0-4, with higher scores indicating more support

[k]Likert scale from “0: None” to “3: Severe”

[l]Early breastfeeding problems scores range from 0 to 18, with higher scores indicating more problems

[m]Likert scale from “1: Disliked very much” to “5: Liked very much”

[n]Parenting Stress Index-Short Form scores range from 36 to 180, with higher scores indicating more stress

Positive emotions during feeding and depression outcomes

In the overall sample, the mean BDI-II score was 8.0 (SD=5.4) at two months, 7.2 (SD=5.5) at six months, and 7.5 (SD=7.0) at 12 months, with significant between-person trajectories of change over time. Approximately 16.5% of the sample met criteria for clinically significant depression (BDI-II≥14) at two months, 15.2% at six months, and 16.5% at 12 months. In crude models, a one-unit increase in positive emotions during feeding was associated with a 1.84 (95% CI: 0.93, 2.75) point decrease in BDI-II score at two months, a 1.97 (95% CI: 1.07, 2.86) point decrease at six months, and a 2.16 (95% CI: 0.90, 3.43) point decrease at 12 months (see Table 2.2 below). These results remained significant but attenuated after adjustment for prenatal depression scores, social support, and concurrent negative emotions during feeding: a one-unit increase in positive emotions was associated with an adjusted 0.96 (95% CI: 0.18, 1.74) point decrease in BDI-II score at two months, a 1.09 (95% CI: 0.35, 1.83) point decrease at six months, and a 1.29 (95% CI: 0.16, 2.42) point decrease at 12 months (Table 2.2). Our results remained robust to sensitivity analyses testing both the exclusion of exclusive formula feeders and women taking psychotropic medications (see Appendix Table 2.2.1).

Baseline diagnosis of clinical depression significantly modified the association between positive emotions and depression scores (LRT=6.0, p=0.01). Among women with no clinical depression in pregnancy, comprising those with both a history of depression or anxiety and those with no history, positive emotions during feeding were associated with significantly lower BDI-II scores at 2, 6, and 12 months. No significant association was observed among women with an active depression diagnosis in pregnancy (Table 2.2 and Figure 2.1 below).

Similar but weaker patterns were observed for the clinically significant depression outcome. Stronger effects of positive emotions during feeding were observed for women without

a prenatal diagnosis of active depression: a one-unit increase in positive emotions was associated with significantly lower odds of clinically significant depression symptoms (BDI ≥ 14) at two and six months among women without an active prenatal depression diagnosis (Table 2.2).

Table 2.2: Estimates of association between a one-unit increase in positive emotions during infant feeding at 2 months and postpartum depression and anxiety outcomes at 2, 6, and 12 months

	N	2 months	6 months	12 months	
Continuous depression outcome (BDI-II)[a]		*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*	*LRT (p-value)*
Mean score (SD)		8.0 (5.4)	7.2 (5.5)	7.5 (7.0)	
Crude Model	164	**-1.84 (-2.75, 0.93)**	**-1.97 (-2.86, -1.07)**	**-2.16 (-3.43, -0.90)**	
Overall Adjusted Model	164	**-0.96 (-1.74, -0.18)**	**-1.09 (-1.83, -0.35)**	**-1.29 (-2.42, -0.16)**	
By baseline psychopathology, adjusted model[b]					6.0 (**p=0.01**)
No active prenatal depression	125	**-1.41 (-2.33, -0.50)**	**-1.54 (-2.44, -0.64)**	**-1.74 (-3.01, -0.47)**	
Active prenatal depression diagnosis	39	-0.33 (-2.15, 1.48)	-0.46 (-2.27, 1.35)	-0.66 (-2.68, 1.36)	
Clinically significant depression (BDI-II ≥14)[a]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*	
N (%)		27 (16.5)	25 (15.2)	27 (16.5)	
Crude Model	164	**0.36 (0.17, 0.75)**	**0.40 (0.22, 0.74)**	**0.47 (0.22, 0.99)**	
Overall Adjusted Model	164	0.55 (0.29, 1.06)	0.61 (0.37, 1.03)	0.72 (0.36, 1.42)	
By baseline psychopathology, adjusted model[b]					3.8 (p=0.05)
No active prenatal depression	125	**0.44 (0.21, 0.92)**	**0.48 (0.26, 0.90)**	0.57 (0.26, 1.22)	
Active prenatal depression diagnosis	39	0.67 (0.20, 2.19)	0.74 (0.24, 2.26)	0.87 (0.26, 2.89)	
Continuous anxiety outcome (STAI-S)[c]		*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*	
Mean score (SD)		28.6 (7.4)	28.2 (6.5)	29.7 (8.0)	
Crude Model	164	**-1.94 (-3.16, -0.73)**	**-1.81 (-2.92, -0.70)**	**-1.62 (-3.05, -0.19)**	
Overall Adjusted Model	164	-0.61 (-1.71, 0.63)	-1.02 (-2.64, 0.61)	-0.71 (-2.89, 1.48)	
By baseline psychopathology, adjusted model[b]					8.4 (**p=0.004**)
No active prenatal anxiety	121	-0.93 (-2.29, 0.42)	-0.81 (-2.06, 0.45)	-0.61 (-2.14, 0.92)	
Active prenatal anxiety diagnosis	43	**-2.64 (-4.77, -0.50)**	**-2.51 (-4.58, -0.43)**	**-2.31 (-4.56, -0.06)**	
Clinically significant anxiety (STAI-S >40)[c]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*	
N (%)		12 (7.3)	8 (4.9)	16 (9.8)	
Crude Model	164	0.64 (0.26, 1.60)	0.63 (0.31, 1.27)	0.60 (0.25, 1.44)	
Overall Adjusted Model	164	1.22 (0.49, 3.05)	1.17 (0.58, 2.36)	1.10 (0.46, 2.64)	
By baseline psychopathology, adjusted model[b]					10.0

				(**p=0.002**)
No active prenatal anxiety	121	1.18 (0.20, 6.89)	1.47 (0.59, 3.62)	1.37 (0.49, 3.85)
Active prenatal anxiety diagnosis	43	0.32 (0.09, 1.14)	**0.30 (0.10, 0.96)**	**0.28 (0.06, 0.98)**

Mixed models were used to estimate the crude and multivariable associations. Linear mixed models for continuous depression/anxiety outcomes included a random intercept to allow baseline depression/anxiety scores to differ among participants, a random effect for time to account for interperson differences in scores over time, and a variance components covariance structure to account for intraperson correlations across repeat measures. For binary outcomes, generalized linear mixed models included a random intercept and unstructured covariance structure. All adjusted models controlled for prenatal depression (BDI-II) or anxiety (STAI-S) scores, social support, and concurrent negative emotions during infant feeding at two months.

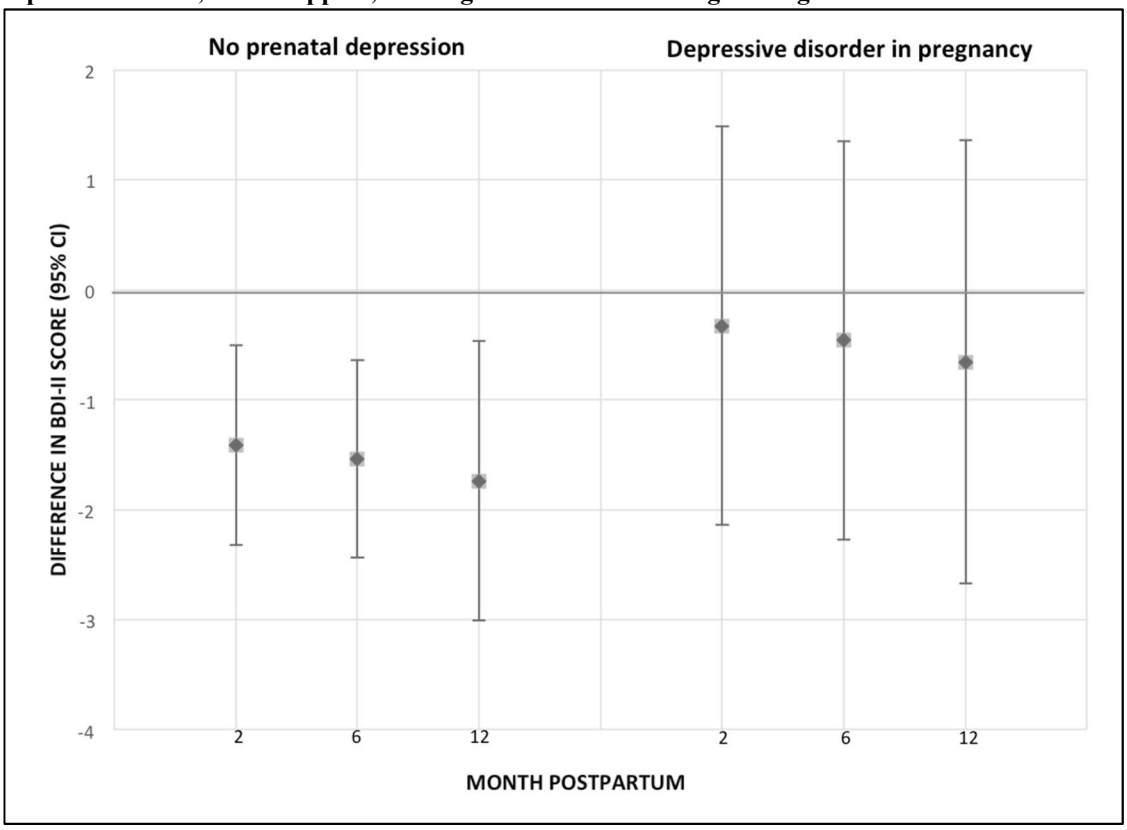
Bolded results are significant at $p<0.05$.

[a] BDI-II: Beck Depression Inventory II scores range from 0 to 63, with higher scores indicating more depression symptoms

[b] Baseline psychopathology was determined via Structured Clinical Interview for DSM-IV in the third trimester of pregnancy. The "no diagnosis" group includes both those with no history and those with a history of depression/anxiety, whereas the "prenatal diagnosis" group met criteria for active disorder during pregnancy

[c] STAI-S: Spielberger State Trait Anxiety Inventory-State scores range from 20-80, with higher scores indicating more anxiety symptoms.

Figure 2.1: The association between a one-point increase in positive emotions during infant feeding and depression scores (BDI-II) at 2, 6, and 12 months, by baseline depression status and adjusted for baseline depression scores, social support, and negative emotions during feeding



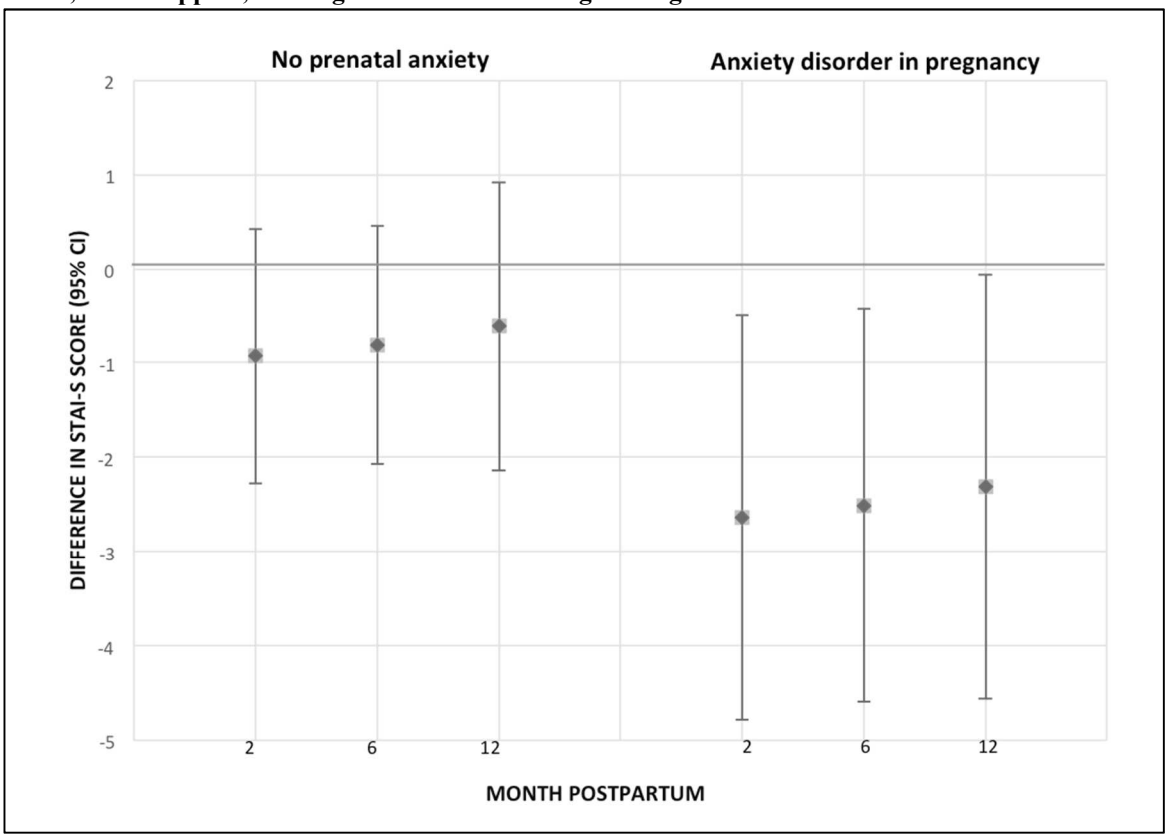
Positive emotions during feeding and anxiety outcomes

The mean STAI-S anxiety score in the sample was 28.6 (SD=7.4) at two months, 28.2 (SD=6.5) at six months, and 29.7 (SD=8.0) at twelve months. Approximately 7.3% of the sample met criteria for clinically significant anxiety (STAI-S>40) at two months, 4.9% at six months, and 9.8% at 12 months. In crude models, a one-unit increase in positive emotions during feeding was associated with a 1.94 (95% CI: 0.73, 3.16) point decrease in STAI-S score at two months, a 1.81 (95% CI: 0.70, 2.92) point decrease at six months, and a 1.62 (95% CI: 0.19, 3.05) point decrease at 12 months (see Table 2.2 above). These associations were attenuated and became nonsignificant after adjustment for baseline anxiety scores, social support, and concurrent negative emotions (Table 2.2).

The association between positive emotions and anxiety scores was significantly different by baseline anxiety disorder diagnosis (LRT=8.4, p=0.004); however, in contrast to depression, women with an active anxiety diagnosis demonstrated a stronger inverse association between positive emotions and anxiety scores (see Figure 2.2 below). Among women with clinical anxiety at baseline, positive emotions were associated with significantly lower postpartum anxiety at 2, 6, and 12 months.

Positive emotions during feeding were not associated with clinically significant anxiety symptoms (STAI > 40) in the overall sample; however, as with continuous anxiety scores, stronger associations were observed among women with an active prenatal anxiety disorder. Among women with clinical anxiety in pregnancy, a one-unit increase in positive emotions was associated with 0.32 (0.09, 1.14) times the odds of clinically significant anxiety at two months, 0.30 (0.10, 0.96) times the odds at six months, and 0.28 (0.06, 0.98) at 12 months (Table 2.2). Sensitivity analyses yielded similar results (see Appendix Table 2.2.1).

Figure 2.2: The association between a one-point increase in positive emotions during infant feeding and anxiety scores (STAI-S) at 2, 6, and 12 months, by baseline anxiety status and adjusted for baseline anxiety scores, social support, and negative emotions during feeding



Conclusions

Among women without a diagnosis of depression during pregnancy, positive emotions during feeding were inversely associated with depression symptoms at 2, 6, and 12 months postpartum, controlling for baseline depression scores, social support, and negative emotions during infant feeding. Positive emotions during feeding were not associated with depressive symptoms among women who were depressed during pregnancy. On the other hand, among women with a diagnosis of an anxiety disorder during pregnancy, positive emotions were associated with significantly lower postpartum anxiety symptoms; among women without an anxiety disorder during pregnancy, positive emotions were not associated with postpartum anxiety symptoms.

The association between positive emotions and depression outcomes, measured both as continuous symptom scores and as odds of exceeding a threshold symptom score, was stronger among women who were not actively depressed during pregnancy. High negative affect has been shown to attenuate associations with positive emotions in other contexts; for example, an observational study of women with HIV found that the association between positive emotions and viral load suppression weakened at elevated levels of negative affect (Wilson et al., 2016). Depressed individuals experience disturbances in positive emotional functioning with attentional biases toward negative information, an inability to sustain positive affect over time, and less activation of associated reward circuitry (Carl, Soskin, Kerns, & Barlow, 2013; Heller et al., 2009). These cognitive distortions may reduce the potential benefits of positive emotions during infant feeding among women already diagnosed with a depressive disorder.

In contrast to depression outcomes, the protective association between positive emotions and anxiety was stronger among women with a prenatal diagnosis of an anxiety disorder. We speculate that positive emotions during infant feeding may buffer against developing postpartum anxiety symptoms by improving psychological resilience to stress (Fredrickson et al., 2003; Tugade & Fredrickson, 2004). In contrast to women with prenatal depression, those with prenatal anxiety who experience positive emotions may benefit from the anxiolytic effects of oxytocin during breastfeeding (M. Newton & Newton, 1948; Niwayama et al., 2017; Stuebe, Grewen, & Meltzer-Brody, 2013b).

This is the first study to explore an association between positive emotions during infant feeding and postpartum mental health. Strengths of this investigation include the extensive longitudinal data on women's mental health, infant feeding, and descriptive characteristics, which address some limitations of previous correlational research (Lyubomirsky et al., 2005).

We adjusted for baseline depression and anxiety scores and explored modification by prenatal SCID-confirmed depression and anxiety to control for baseline mental health status, isolating the association between positive emotions during feeding and later mental health outcomes. Unmeasured confounding is reduced due to breadth of data collected over time on study subjects and the minor amount of missingness. Finally, we applied Fredrickson's broaden-and-build theory to a new and understudied population, mother-infant dyads in the perinatal period. Our findings support the importance of examining the role of maternal relational experiences during infant feeding and maternal mental health, given that few treatments for postpartum depression/anxiety address the mother-infant relationship (Forman et al., 2007; Letourneau et al., 2017).

Our findings should be interpreted in the context of study limitations. To be included in the study, subjects needed to intend to breastfeed at least two months; as a result, study participants were more highly motivated to breastfeed than the general population. Moreover, women with severe depression/anxiety were likely less willing or able to participate in this intensive longitudinal study. Our study sample was predominantly Non-Hispanic White, partnered, and highly educated, limiting our ability to consider modification by race/ethnicity or SES; such work is needed given well-established associations between these social determinants of health and both infant feeding and mental health. Future research on positive emotions during infant feeding or while engaged in other bonding activities should be conducted among women of color and groups with lower breastfeeding intentions.

Self-report measures used in analyses may have led to reporting bias, especially to the extent that affective responses are influenced by concurrent depression/anxiety. While the mDES has not been previously used in the context of infant feeding, it has been validated across

numerous contexts (Cohn et al., 2009; Fredrickson et al., 2008), and we conducted a factor analysis that confirmed the positive emotions subscale best represented one coherent construct in relation to infant feeding (see Appendix Figure 1.1.1). Our analysis examined positive emotions during feeding at a single timepoint; future studies would benefit from exploring the emotional experience of infant feeding over time to quantify temporal dynamics of positive emotions and postpartum mental health. Finally, the relationship between positive emotions and depression/anxiety may be bi-directional. In an effort to reduce the likelihood of confounding by baseline psychopathology, we used longitudinal data to support the temporality of our hypothesized associations and we stratified on active diagnoses of prenatal depression/anxiety.

Conclusions

According to the broaden-and-build theory of positive emotions, experiences of positive emotions trigger upward spirals that improve mental health and well-being (Fredrickson, 2004). Our study provides preliminary evidence for an association between positive emotions during infant feeding and postpartum mental health. These results can inform future clinical interventions to target the positive affect system in the perinatal period, leveraging the nurturing relationship between mother and infant to improve postpartum mental health.

CHAPTER 3 - POSITIVE EMOTIONS DURING INFANT FEEDING AND BREASTFEEDING OUTCOMES

Overview

Background: Few studies have examined the role of maternal emotions in breastfeeding outcomes. We explored the extent to which maternal positive emotions during breast milk feeding at two months were associated with time to any and exclusive breast milk feeding cessation and overall maternal breastfeeding experience.

Methods: 192 women intending to breastfeed for at least two months were followed from the third trimester through 12 months postpartum. We measured positive emotions during infant feeding at two months using the mean subscale score of the modified Differential Emotions Scale (range: 0-4). We used Cox proportional hazards regression to estimate adjusted hazard ratios (aHR) for time to any and exclusive breast milk feeding cessation associated with a one-point increase in positive emotions. We also used linear regression to estimate the association between positive emotions and maternal report of overall breastfeeding experience at 12 months.

Results: Among women breast milk feeding at two months, positive emotions during feeding were not associated with breast milk feeding cessation by 12 months (aHR=0.94, 95% CI: 0.64, 1.31). However, among women exclusive breast milk feeding at two months, a one-point increase in positive emotions was associated with a 35% lower hazard of introducing formula or solid foods by six months (aHR=0.65, 95% CI: 0.46, 0.92). Positive emotions were also associated with a significantly more favorable maternal report of overall breastfeeding

experience at 12 months. Results were similar in sensitivity analyses using maternal feelings about breastfeeding in the first week postpartum as the exposure.

Conclusions: Maternal positive emotions during breastfeeding may be a modifiable factor for improving breastfeeding outcomes.

Background

Breastfeeding is associated with a number of well-established health benefits for both mothers and infants (Horta et al., 2015b; Ip et al., 2007; Sankar et al., 2015; Victora et al., 2016). As a result of these benefits, major medical organizations in the U.S. recommend exclusive breastfeeding for six months, with continued breastfeeding through the first year "or longer as mutually desired by the woman and her infant" (American Academy of Family Physicians, 2014; American Academy of Pediatrics Section on Breastfeeding, 2012; The American College of Obstetricians and Gynecologists, 2016). In the US, approximately 82.5% of women initiated breastfeeding in 2014, the last year for which national data are available, indicating a widespread desire to breastfeed; however, only 24.9% of women reported exclusive breastfeeding at six months and only 33.7% reported any breastfeeding at one year (Centers for Disease Control and Prevention, 2017), falling short of public health recommendations.

The maternal experience of breastfeeding has not been rigorously studied; however, preliminary evidence suggests that maternal affect and feelings toward breastfeeding may affect breastfeeding outcomes. A systematic review of psychosocial correlates of exclusive breastfeeding found three studies showing that positive maternal attitudes toward breastfeeding were associated with a higher likelihood of exclusive breastfeeding compared with ambivalent or negative attitudes (de Jager et al., 2013). In an Australian cohort, maternal breastfeeding satisfaction was a stronger predictor of time to weaning than breastfeeding problems (Cooke et

al., 2003). Another study found that maternal negative affect during pregnancy was associated with an increased odds of mixed breastfeeding and bottle-feeding at six months postpartum (Ystrom et al., 2008). A positive emotional experience of breastfeeding may also have implications for outcomes besides duration and exclusivity. Leff et al. found that maternal enjoyment and attainment of one's desired maternal role were identified by mothers as more important for "successful" breastfeeding than duration (Leff, Gange, et al., 1994). Qualitative research has found that women who described breastfeeding as pleasurable and enjoyable describe feeling an intimate connection with the infant, maternal confidence, and adequate support (E. Burns et al., 2010). In 1955, breastfeeding researcher Niles Newton wrote in her dissertation: "More research which considers the whole nature of the breast feeding situation is badly needed. The number of months of breastfeeding are probably much less important psychologically than the type of breastfeeding and the type of weaning involved. Was the breastfeeding unsuccessful breastfeeding—with all the tension, fear, and pain that that involves? Or was it successful breastfeeding with its peace of mind and physical pleasure?" (N. Newton, 1955).

Barbara Fredrickson's broaden-and-build theory of positive emotions suggests that experiences of positive emotions lead to adaptive benefits by broadening one's thought-action repertoire, facilitating the accrual of personal and social resources to improve health and well-being. Positive psychology interventions that increase experiences of positive emotions have been shown to experimentally improve resilience to future stressors through resources such as social support (Fredrickson et al., 2008) and coping skills (A. B. Burns et al., 2008; Fredrickson & Joiner, 2002). In the context of the postpartum period, the broaden-and-build theory suggests

that positive emotions experienced during breastfeeding may broaden the scope of a mother's thoughts and actions, allowing her to build the resources necessary to cope with challenges.

This study tested the extent to which positive emotions during breast milk feeding at two months were associated with longer duration of any and exclusive breast milk feeding. We also estimated the association between positive emotions at two months and women's overall experience of breastfeeding at 12 months. We hypothesized that women with higher positive emotions at two months would sustain a longer duration of any and exclusive breast milk feeding cessation and report a better overall experience of breastfeeding at 12 months, compared to women with lower positive emotions. We explored modification of these relationships by maternal psychopathology in pregnancy.

Methods

Sample

Our sample was drawn from 220 pregnant women enrolled in the longitudinal cohort study *Mood, Mother and Infant: The Psychobiology of Impaired Dyadic Development* (MMI) and followed from the third trimester until 12 months postpartum. This cohort comprised women living near Chapel Hill, North Carolina recruited from study fliers and obstetric or psychiatric visits. Women with an elevated risk for postpartum depression and anxiety were oversampled. Risk status was ascertained based on a Structured Clinical Interview for DSM-IV (SCID)-confirmed history of depression/anxiety or active depressive/anxiety disorder in pregnancy; by design, about 1/3 of women had a SCID-verified history of depression or anxiety, and 1/3 had an active diagnosis. Eligible participants were 18-45 years old, enrolled at 34-37 weeks' gestation of a singleton pregnancy, able to communicate in English, and intending to breastfeed at least two months. Women were excluded from the study if they met any of the following criteria:

history or current diagnosis of psychiatric disorders other than depression/anxiety; substance abuse; NICU admission >48 hours, major congenital anomaly, or neonatal death; use of tricyclic antidepressants; or contraindication for breastfeeding. A full description of the study can be found at http://mmi.web.unc.edu.

For this analysis, we restricted to participants completing their 12-month visit by January 2018 (n=205). We excluded women missing exposure data (n=12) and one who withdrew before contributing any breastfeeding outcome data. The remaining 192 women comprise our analytic sample.

Measures

Baseline data were collected through questionnaires and interviews with study staff at the third trimester laboratory visit. Follow-up contacts occurred through monthly phone interviews and laboratory visits at 2, 6, and 12 months postpartum.

Exposure

We measured positive emotions during infant feeding at two months using the modified Differential Emotions Scale (mDES). The mDES asks the "greatest amount" 10 positive and 10 negative emotions were experienced during infant feeding over the past week using a 5-point Likert scale (0=not at all, 4=extremely). The mDES was adapted from Izard's Differential Emotions Scale (Izard, 1977) and has a high internal reliability ranging from 0.82-0.94 (Cohn et al., 2009; Fredrickson et al., 2008). Our exposure uses the positive emotions subscale of the mDES, which provides a mean score with range from 0-4 across 10 discrete emotions: amusement, awe, contentment, gratitude, hope, joy, interest, love, pride, and inspiration.

Because this is the first time the mDES was applied in the context of infant feeding, we conducted a confirmatory factor analysis indicating the 10 positive emotions are unidimensional

with roughly equal factor loadings (CFI=0.9530) (see Appendix Figure 1.1.1). The experience of positive emotions during infant feeding at two months was analyzed as a continuous exposure and compared for consistency with alternate categorizations, such as binary (at the mean, median, and cutpoints between 2-3), tertiles, quartiles, and splines, based on the distributions observed in the data. Using a priori criteria of model fit, we chose a continuous exposure measure and estimated effects associated with a one-point increase in positive emotions in all analyses. We used a dichotomous exposure of high (>2.5) versus low (<=2.5) positive emotions, which had the second most optimal model fit, to present descriptive characteristics and Kaplan-meier survival curves.

Women who had discontinued breastfeeding by two months were censored from the primary analytic sample, leading to possible selection bias due to immortal person time. Immortal person time occurs because the mDES exposure was first measured at two months postpartum, thereby excluding from analyses those women who stopped any or exclusive breast milk feeding before that time. To address this bias, sensitivity analyses were conducted using a measure of maternal feelings about breastfeeding in the first week postpartum. This exposure measure was defined by asking women how they felt about breastfeeding during the first week postpartum using a Likert scale (1=Disliked very much, 5=Liked very much). By repeating analyses with a measure of maternal feelings about breastfeeding in the first week postpartum, we retained the entire sample to determine if results differed due to selection bias. We also repeated analyses using the measure of maternal feelings about breastfeeding in the first week postpartum in the immortal person-time-flawed sample of women doing any breast milk feeding at two months to assess whether both exposures showed similar estimates of effect. As with the

main exposure, we chose a continuous measure of positive feelings in the first week to estimate effects associated with a one-point increase.

Outcome

Every month between 1 and 12 months postpartum, mothers were asked about how many times on average over the previous week their infant was fed breast milk (including at-breast, expressed, or donor human milk), formula, or solid foods. Mothers were also asked if their infant had been fed formula since the previous study interview or visit. Time to cessation of any breast milk feeding was defined using the infant age in weeks from birth to the date of the visit when the mother reported no longer feeding any breast milk in the previous week. Women who still reported any breast milk feeding at the final visit were censored at that date. Time to cessation of exclusive breast milk feeding was defined using the infant age in weeks from birth to the date of the visit when the mother reported feeding formula or solid foods in the previous week or formula any time since the previous study interview or visit. Women who still reported exclusive breast milk feeding at the six month-visit were censored at that date.

Women's overall experience of breastfeeding was assessed using the Maternal Breastfeeding Evaluation Scale (MBFES) at 12 months postpartum. The MBFES asks women to consider their overall experience of breastfeeding and/or expressing milk for their most recent baby, comprising 30 items such as "It was a burden being my baby's main source of food" and "My baby and I worked together to make breastfeeding go smoothly" (Leff, Jefferis, et al., 1994). Women responded using a 4-point Likert scale (0=strongly disagree, 4=strongly agree). This tool has been shown to have a high reliability with a Cronbach's alpha of 0.93 (Leff, Jefferis, et al., 1994). For this analysis, the total MBFES score was considered the primary outcome. Continuous subscores were also analyzed for the following three dimensions of

maternal breastfeeding experiences on the MBFES: maternal enjoyment/role attainment, infant satisfaction/growth, and lifestyle/maternal body image (Leff, Jefferis, et al., 1994).

Potential Covariates

We used a directed acyclic graph (DAG) (Greenland et al., 1999) to identify potential confounders (see Appendix Figure 3.1.1): prenatal depression symptom burden via Beck Depression Inventory and anxiety symptom burden via State Trait Anxiety Inventory-State scores; moderate/severe childhood trauma via Childhood Trauma Questionnaire (Bernstein & Fink, 1998); attachment via Maternal Antenatal Attachment Scale; infant feeding intention via the Infant Feeding Intentions Scale in the third trimester (Nommsen-Rivers & Dewey, 2009); birth trauma via Modified Perinatal Post-Traumatic Stress Disorder Questionnaire; early breastfeeding problems in the first two weeks; professional lactation support indexed by having received help with breastfeeding from a lactation consultant in the hospital; infant temperament via Carey Early Infancy Temperament Questionnaire (Medoff-Cooper et al., 1993); social support via Medical Outcomes Study Social Support Survey (Sherbourne & Stewart, 1991); return to work by two months; and concurrent negative emotions during infant feeding via mDES to highlight the unique contribution of positive emotions beyond the presence or absence of negative emotions (A. B. Burns et al., 2008; Waugh & Fredrickson, 2006).

We also explored modification of the association between positive emotions and breastfeeding outcomes by women's baseline psychopathology: we tested modification by the presence or absence of clinical depression/anxiety during pregnancy via third trimester SCID and by risk status for postpartum depression/anxiety, where "high risk" was indexed by a SCID-confirmed history of depression/anxiety or an active depressive/anxiety disorder in pregnancy.

Secondary analyses explored modification by infant feeding status at the time of exposure assessment.

Statistical analyses

We used Cox proportional hazards regression to estimate hazard ratios for time to any and exclusive breast milk feeding cessation associated with a one-point increase in positive emotions. Women who were exclusively formula feeding at two months were excluded from the analysis of time to cessation of any breast milk feeding, and women not exclusively breast milk feeding were excluded from the time to cessation of exclusive breast milk feeding, as they could not contribute any time to event outcome data. Linear regression was used to estimate the crude and multivariable associations between experiences of positive emotions during infant feeding at two months and the total score and subscores of overall breastfeeding experience at 12 months.

Confounders were included in the multivariable Cox regression models where they were identified as important to adjust for based on subject-matter knowledge as represented in the DAG (Dagitty, version 2.3) and removed if collinearity with other variables caused model instability indexed by inflated estimates or standard errors. We computed crude Kaplan-Meier curves to illustrate time to any and exclusive breastfeeding by high (>2.5) versus low (<=2.5) positive emotions (see Appendix 3.1 for more information about confounder-controlled Kaplan-Meier curves). Crude and adjusted estimates and their associated 95% confidence intervals (CI) are presented for all models. Effect measure modification was considered to be present where p-values on interaction terms were <0.05.

Senstivity analyses repeated the above models using the measure of how much the mother reported liking breastfeeding in the first week postpartum, using both the full sample of mothers doing any breast milk feeding at week one and the restricted sample of mothers doing

any breast milk feeding at month two (see Appendix 3.2 for additional sensitivity analyses excluding women taking psychotropic medications). All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Study sample characteristics

Descriptive characteristics are presented for the 192 women in the study sample by high (>2.5 to 4) versus low (0 to 2.5) positive emotions scores (see Table 3.1 below). The mean positive emotions score was 2.8 (SD=0.8), with 66.2% of the sample classified as experiencing high positive emotions. Approximately 60% of the sample were exclusive breast milk feeding at two months, 31% were not exclusive feeding but feeding some breast milk, and 9% were exclusive formula feeding, with no significant differences in positive emotions. About 73% of the sample were Non-Hispanic White, almost half reported a post-graduate level of education, and 88% were married/partnered, with no significant differences in positive emotions by sociodemographic characteristics. One third of the sample had not met their prenatal breastfeeding intention by two months, with no significant differences in positive emotions among those who had met vs. not met their prenatal intention. Women with higher positive emotions during infant feeding at two months were significantly more likely to have had a vaginal birth, practiced skin-to-skin in the first hour after birth, returned to work by two months, and report higher levels of antenatal attachment, social support, and positive feelings about breastfeeding in the first week postpartum. Women with higher positive emotions during feeding were also significantly less likely to experience concurrent negative emotions during feeding, a traumatic birth experience, early breastfeeding problems, or parenting stress at two months (Table 3.1).

Table 3.1. Descriptive statistics for Aim 2 sample by low (0-2.5) versus high (>2.5-4) positive emotions

Variable	Overall		Low Positive Emotions[a]		High Positive Emotions[a]		p-value[b]
	Mean (SD) or N	(%)	Mean (SD) or N	(%)	Mean (SD) or N	(%)	
Total	192		65	(33.9)	127	(66.2)	
Positive emotions during infant feeding at 2 months[a]	2.8 (0.8)		1.9 (0.6)		3.3 (0.4)		**<0.001**
Infant feeding status at 2 months							0.36
Exclusive breast milk feeding	114	(59.4)	34	(52.3)	80	(63.0)	
Any breast milk feeding, not exclusive	60	(31.3)	24	(36.9)	36	(28.4)	
No breast milk feeding	18	(9.4)	7	(10.8)	11	(8.7)	
Baseline psychopathology[c]							0.52
Low risk	58	(36.0)	18	(31.0)	41	(38.7)	
High risk, history of depression/anxiety	51	(31.1)	18	(31.0)	33	(31.1)	
High risk, active depression/anxiety disorder in pregnancy	54	(32.9)	22	(37.9)	32	(30.2)	
Race/ethnicity							0.34
Non-Hispanic White	141	(73.4)	51	(78.5)	90	(70.9)	
Non-Hispanic Black	19	(9.9)	4	(6.2)	15	(11.8)	
Hispanic, any race	21	(10.9)	5	(6.2)	16	(12.6)	
Other	11	(5.7)	5	(7.7)	6	(4.7)	
Education Level							0.77
Some high school or high school grad	12	(6.3)	5	(7.7)	7	(5.5)	
Some college or college grad	92	(47.9)	32	(49.2)	60	(47.2)	
Post-graduate level	88	(45.8)	28	(43.1)	60	(47.2)	
Marital Status							0.92
Married/partnered	169	(88.0)	57	(87.7)	112	(88.2)	
Single/divorced	23	(12.0)	8	(12.3)	15	(11.8)	
Parity							0.81
Nulliparous	104	(54.2)	36	(55.4)	68	(53.5)	
Multiparous	88	(45.8)	29	(44.6)	59	(46.5)	

Psychotropic medication between baseline and 2 months[d]							0.05
Yes	59	(30.7)	26	(40.0)	33	(26.0)	
No	133	(69.3)	39	(60.0)	94	(74.0)	
Met prenatal breastfeeding intention at 2 months[e]							0.46
Yes	125	(65.1)	40	(61.5)	85	(66.9)	
No	67	(34.9)	25	(38.5)	42	(33.1)	
Missing	2	(1.0)	1	(1.5)	1	(0.8)	
Returned to work by 2 months							**0.02**
Yes	57	(29.7)	12	(18.5)	45	(35.4)	
No	133	(69.3)	52	(80.0)	81	(63.8)	
Missing	2	(1.0)	1	(1.5)	1	(0.8)	
Moderate to Severe Childhood Trauma Experience[f]							0.38
Yes	54	(28.1)	16	(24.6)	38	(29.9)	
No	132	(68.8)	48	(73.8)	84	(66.1)	
Missing	6	(3.1)	1	(1.5)	5	(3.9)	
Skin-to-skin practiced in the first hour postpartum							**0.01**
Yes	179	(93.7)	57	(87.7)	122	(96.8)	
No	12	(6.3)	8	(12.3)	4	(3.2)	
Missing	1	(0.01)			1	(0.01)	
Type of birth							**0.04**
Vaginal	162	(84.4)	50	(76.9)	112	(88.2)	
Cesarean section	30	(15.6)	15	(23.1)	15	(11.8)	
Received in-hospital breastfeeding help from lactation consultant							0.47
Yes	157	(81.2)	55	(84.6)	102	(80.3)	
No	35	(18.2)	10	(15.4)	25	(19.7)	
Negative emotions during infant feeding[a]	0.6 (0.6)		0.7 (0.6)		0.5 (0.5)		**0.01**
Infant feeding intention[g]	14.6 (2.3)		14.4 (2.5)		14.9 (1.9)		0.11
Traumatic birth experience[h]	6.4 (6.8)		8.2 (7.3)		5.6 (6.4)		**0.01**
Infant temperament at 2 months[i]	27.6 (3.3)		27.8 (3.5)		27.4 (3.3)		0.44
Antenatal attachment[j]	76.4 (6.2)		74.0 (6.9)		77.7 (5.4)		**<0.001**

Social support at 2 months[k]	3.4 (0.7)	3.3 (0.7)	3.5 (0.6)	**0.01**
Breastfeeding problems in first 2 weeks[l]	4.1 (2.0)	4.6 (2.0)	3.9 (1.9)	**0.02**
Breast pain, day one postpartum[m]	1.01 (0.9)	1.15 (0.9)	0.94 (0.9)	0.12
Positive feelings about breastfeeding in first week,[n] *median (IQR)*	4 (2-5)	3 (2-4)	4 (3-5)	**0.001**
Parenting stress at 2 months[o]	66.8 (17.3)	77.4 (16.5)	61.7 (15.3)	**<0.001**

[a]mDES scores range from 0 to 4, with higher scores indicating more emotions; descriptive statistics are presented by high positive emotions (score of >2.5-4) and low positive emotions (0-2.5).
[b]Independent samples t-test for continuous variables; chi-square test and fisher's exact test for categorical variables
[c]Based on Structured Clinical Interview for Diagnosis (SCID) criteria for a history of or current depression (including Major Depressive Disorder, Dysthymic Disorder, Depressive Disorder NOS, or Postpartum Depression) or anxiety (including Panic Disorder, Agoraphobia, Social Phobia, Obsessive Compulsive Disorder, Generalized Anxiety Disorder, or Post Traumatic Stress Disorder), administered in the third trimester of pregnancy
[d]Includes self-reported use of any of the following medications: antidepressants, benzodiazepines, antipsychotics, and hypnotics
[e]Defined as meeting prenatal intention for any and exclusive breastfeeding
[f]Defined as meeting the threshold for moderate/severe emotional abuse, physical abuse, sexual abuse, emotional neglect, or physical neglect on the 28-item Childhood Trauma Questionnaire
[g]Infant Feeding Intentions Scale scores range from 0-16, with higher scores indicating a stronger intent to initiate and sustain exclusive breastfeeding
[h]Modified Perinatal Post-Traumatic Stress Disorder Questionnaire scores range from 0-56, with higher scores indicating more perinatal ptsd
[i]Carey Early Infancy Temperament Questionnaire (EITQ) comprises 9 categories of temperament, with higher scores indicating more difficult/negative qualities.
[j]Maternal Antenatal Attachment Scale scores range from 19-95, with higher scores indicated stronger attachment
[k]Medical Outcomes Study Social Support Survey (MOS) scores range from 0-4, with higher scores indicating more support
[l]Early breastfeeding problems scores range from 0 to 18, with higher scores indicating more problems
[m]Likert scale from "0: None" to "3: Severe"
[n]Likert scale from "1: Disliked very much" to "5: Liked very much"
[o]Parenting Stress Index-Short Form scores range from 36 to 180, with higher scores indicating more stress

Positive emotions and time to cessation of any breast milk feeding

The crude Kaplan-Meier curves for time to cessation of any breast milk feeding were not significantly different by high versus low positive emotions (see Figure 3.3 below and weighted Kaplan-Meier curves in Appendix 3.2). A one-point increase in positive emotions at two months was associated with 0.94 (95% CI: 0.64, 1.31) times the hazard of stopping any breast milk feeding, adjusted to control for confounding by baseline depression scores, social support, receiving professional breastfeeding support from lactation consultant in the hospital, breastfeeding problems in the first two weeks, birth trauma, and negative emotions during feeding at two months (see Table 3.2 below). This association was not significantly different by women's baseline psychopathology (LRT p=0.82) (see Appendix Table 3.2.1). Results were similar in sensitivity analyses conducted using both the same restricted sample as main analyses and using the entire sample of women doing any breast milk feeding at one week postpartum (Table 3.2).

Figure 3.3: Crude Kaplan-Meier curves and 95% confidence intervals for time to cessation of any breast milk feeding stratified by high (>2.5-4) versus low (0-2.5) positive emotions during breast milk feeding

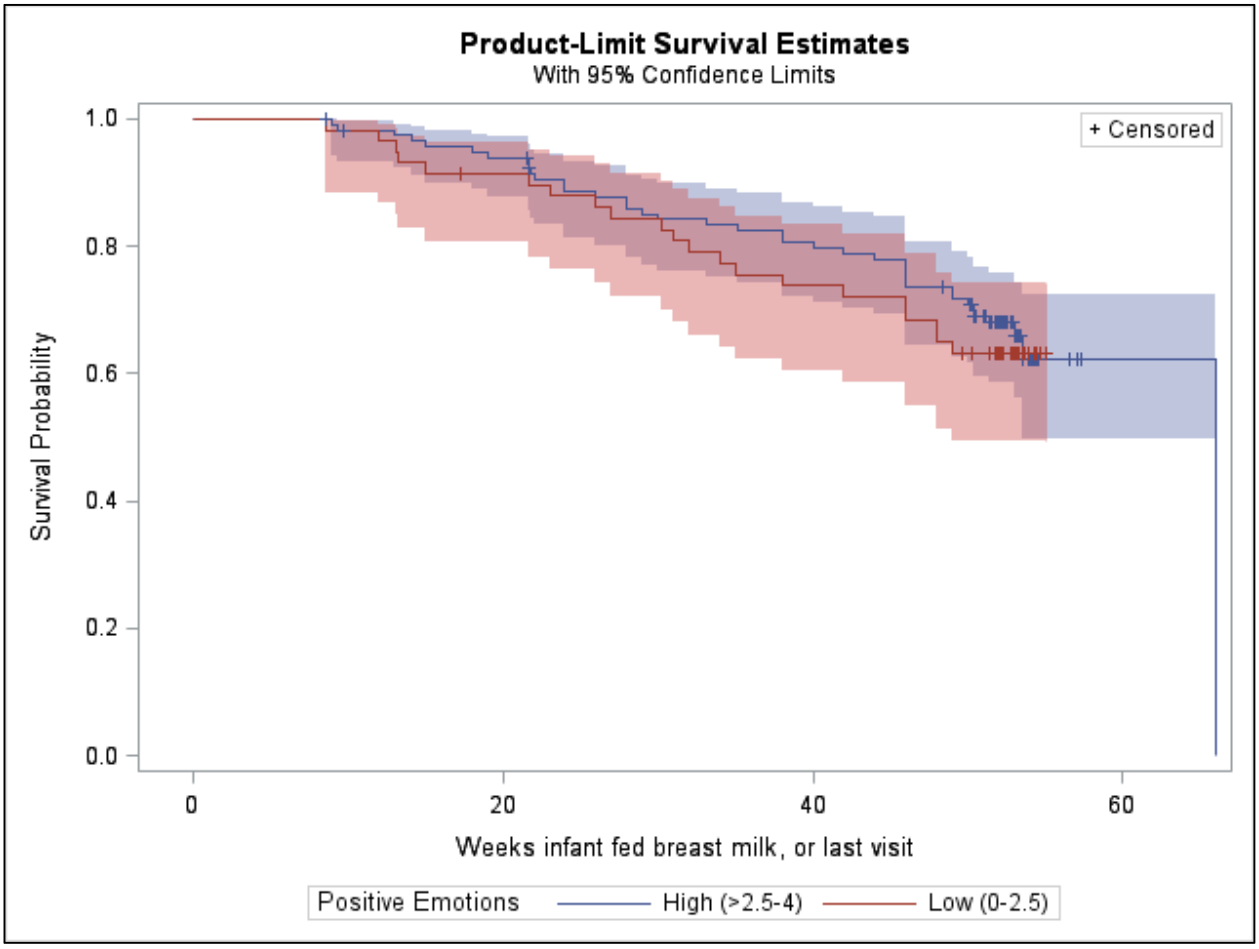


Table 3.2: Estimates of association between a one-unit increase in positive emotions and time to any and exclusive breast milk feeding cessation and overall maternal evaluation of breastfeeding at 12 months

	Any breast milk feeding cessation[a]			Exclusive breast milk feeding cessation[a]		
	N	**Crude**	**Adjusted**	**N**	**Crude**	**Adjusted**
Exposure		*HR (95% CI)*	*HR (95% CI)*		*HR (95% CI)*	*HR (95% CI)*
Positive emotions during breast milk feeding, 2 months[b]	174	0.88 (0.64, 1.20)	0.94 (0.64, 1.31)	114	0.74 (0.53, 1.03)	**0.65 (0.46, 0.92)**
Week 1 positive feelings about breastfeeding, among those breast milk feeding at 2 months[c]	174	**0.78 (0.65, 0.93)**	0.89 (0.72, 1.11)	114	0.85 (0.70, 1.02)	**0.75 (0.60, 0.94)**
Week 1 positive feelings about breastfeeding, among those breast milk feeding at week 1[c]	192	**0.77 (0.65, 0.91)**	0.87 (0.72, 1.06)	185	**0.74 (0.66, 0.84)**	**0.77 (0.66, 0.89)**

[a] Cox proportional hazards regression models were used to estimate hazard ratios (HR) for time to cessation of breast milk feeding and exclusive breast milk feeding.

[b] Models using positive emotions at two months as the exposure were adjusted for confounding by prenatal depression score, social support, professional breastfeeding support from a lactation consultant in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding at two months

[c] Models using positive emotions at one week postpartum as the exposure were adjusted for confounding by prenatal infant feeding intention score, social support, birth trauma, and professional breastfeeding support from a lactation consultant in the hospital.

Bolded results are significant at $p<0.05$.

Table 3.3: Estimates of association between a one-unit increase in positive emotions and maternal evaluation of breastfeeding at 12 months

	Overall breastfeeding experience: MBFES (range 0-120)[a]		
	N	**Crude**	**Adjusted**
Exposure		*Beta (95% CI)*	*Beta (95% CI)*
Positive emotions during infant feeding at 2 months, entire sample[b]	186	**7.11 (4.29, 9.92)**	**5.96 (3.16, 8.76)**
Positive feelings about breastfeeding at week 1, entire sample[c]	186	**5.58 (4.01, 7.16)**	**4.74 (3.12, 6.35)**
	Maternal Enjoyment and Role Attainment Subscale (range 0-56)		
		Beta (95% CI)	*Beta (95% CI)*
Positive emotions during infant feeding at 2 months, entire sample[b]	186	**4.30 (2.68, 5.93)**	**3.88 (2.25, 5.51)**
Positive feelings about breastfeeding at week 1, entire sample[c]	186	**3.24 (2.33, 4.16)**	**2.85 (1.91, 3.79)**
	Infant Satisfaction and Growth Subscale (range 0-32)		
		Beta (95% CI)	*Beta (95% CI)*
Positive emotions during infant feeding at 2 months, entire sample[b]	186	**1.60 (0.40, 2.80)**	1.01 (-0.14, 2.17)
Positive feelings about breastfeeding at week 1, entire sample[c]	186	**1.79 (1.11, 2.46)**	**1.49 (0.79, 2.19)**

		Lifestyle and Maternal Body Image Subscale (range 0-32)	
		Beta (95% CI)	*Beta (95% CI)*
Positive emotions during infant feeding at 2 months, entire sample	186	**2.15 (0.91, 3.39)**	**1.49 (0.28, 2.69)**
Positive feelings about breastfeeding at week 1, entire sample	186	**2.22 (1.54, 2.91)**	**1.83 (1.12, 2.53)**

[a] Linear regression models were used for continuous Maternal Breastfeeding Evaluation Scale total and subscore outcomes

[b] Models using positive emotions at two months as the exposure were adjusted for confounding by prenatal depression score, social support, professional breastfeeding support from a lactation consultant in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding at two months

[c] Models using positive emotions at one week postpartum as the exposure were adjusted for confounding by prenatal infant feeding intention score, social support, birth trauma, and professional breastfeeding support from a lactation consultant in the hospital.

Bolded results are significant at $p<0.05$.

Positive emotions and time to cessation of exclusive breast milk feeding

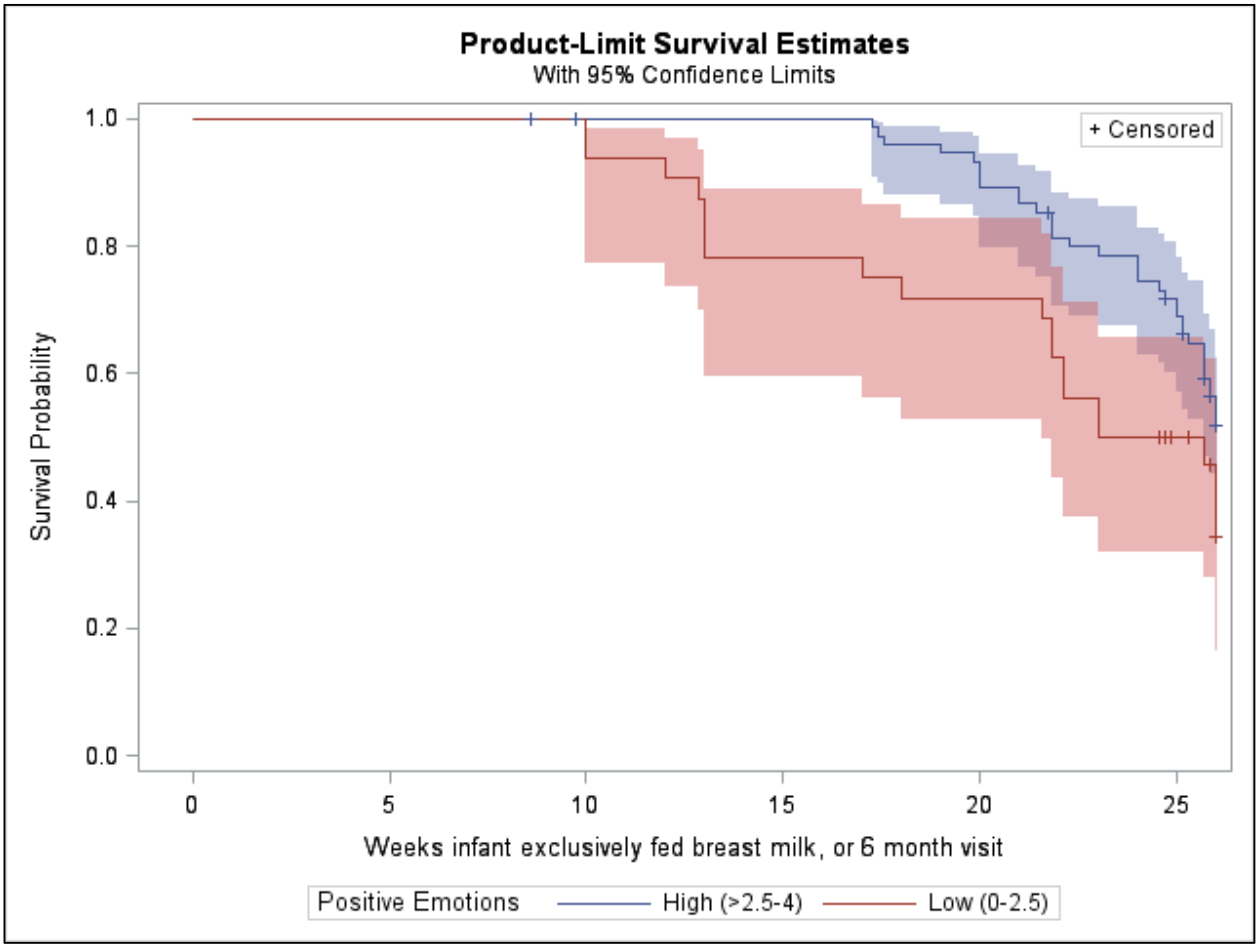
The crude Kaplan-Meier curves for time to cessation of exclusive breast milk feeding were significantly different by high versus low positive emotions (see Figure 3.4 below and weighted Kaplan-Meier curves in Appendix 3.2). A one-point increase in positive emotions at two months was associated with 0.65 (95% CI: 0.46, 0.92) times the hazard of stopping exclusive breast milk feeding, adjusted to control for confounding by baseline depression scores, social support, receiving professional breastfeeding support from lactation consultant in the hospital, breastfeeding problems in the first two weeks, birth trauma, and negative emotions during feeding at two months (see Table 3.2 above). There was no significant modification by baseline psychopathology (LRT p=0.75) (Appendix Table 3.2.1). Results from sensitivity analyses were similar and slightly more precise (Table 3.2).

Positive emotions and overall experience of breastfeeding

In the overall sample, a one-point increase in positive emotions at two months was associated with an adjusted 5.96 (95% CI: 3.16, 8.76) points higher score on the MBFES (Table 3.3). This association was not significantly different by breast milk feeding status (defined as exclusive, mixed feeding, and no breast milk feeding) at two months (p=0.68) (Appendix Table 3.2.3). In secondary analyses probing the overall experience of breastfeeding by MBFES subscale and adjusted for confounders, positive emotions at two months were significantly associated with the maternal enjoyment/role attainment and lifestyle/maternal body image subscales but not with the infant satisfaction/growth subscale (Table 3.3). In adjusted sensitivity analyses using the complete sample, a one-point increase in positive feelings about breastfeeding at one week postpartum was associated with an adjusted 4.74 (95% CI: 3.12, 6.35) point increase

on the MBFES. This earlier exposure measure was also significantly associated with higher scores on all MBFES subscales (Table 3.3).

Figure 3.4: Crude Kaplan-Meier curves and 95% confidence intervals for time to cessation of exclusive breast milk feeding



Discussion

Consistent with our hypothesis, positive emotions during feeding at two months were significantly associated with a longer time to cessation of exclusive breast milk feeding and with a better overall maternal breastfeeding experience. Contrary to our hypothesis, positive emotions at two months were not associated with breast milk feeding cessation across the first year postpartum. Maternal feelings about breastfeeding in the first week yielded similar and more precise associations with all outcomes.

Higher positive emotions during exclusive breast milk feeding at two months were predictive of a significantly longer exclusive breast milk feeding duration. By two months, where mothers are able to exclusively breast milk feed, maternal enjoyment of feeding may provide sufficient motivation to meet public health targets. However, higher positive emotions during any breast milk feeding at two months were not predictive of a significantly longer duration of breast milk feeding. We did not observe modification of this association by breast milk feeding status at two months, exclusive vs. mixed feeding. However, this group of mothers who are any breastfeeding at two months comprises both women who have met their prenatal intention and those who have faced early physiological and/or structural barriers that prevented them from meeting their intended exclusivity goals. This heterogeneity may attenuate the effect of positive emotions seen among those exclusive breast milk feeding. Where a mother is any breast milk feeding at two months but faced many early challenges to exclusive feeding, maternal enjoyment of feeding may reflect satisfaction with the experiential aspects of feeding and less concern about providing breast milk as a product (Auerbach, 1991).

In our sample, women with low positive emotions during feeding at two months were significantly more likely to have also had a cesarean birth, a more traumatic birth experience, and no skin-to-skin with the infant in the first hour after birth. Given the role of the early maternal breastfeeding experience as a modifiable factor for improving long-term breastfeeding outcomes, mothers should be supported to process difficult birth experiences and cope with early breastfeeding challenges. Maternity practices like those implemented through the Baby-Friendly Hospital Initiative (BFHI) have been found to increase breastfeeding duration and exclusivity in several studies (Kramer et al., 2001; Merewood, 2005; Munn, Newman, Mueller, Phillips, & Taylor, 2016). Specific BFHI practices, such as mother-infant skin-to-skin contact in the first

hour after birth, also correlate with later maternal breastfeeding satisfaction even among mothers not intending to breastfeed exclusively (Hongo, Nanishi, Shibanuma, & Jimba, 2015). Collaborative decision-making around infant feeding can help health care providers understand each woman's experiences and constraints to support her own goals for successful breastfeeding (E. Burns, Fenwick, Sheehan, & Schmied, 2013; Schmied & Barclay, 1999). Woman-centered maternity practices that support the relational and experiential aspects of breastfeeding may improve both breastfeeding rates and maternal satisfaction with breastfeeding. The significant association between positive feelings about breastfeeding in the first week and breastfeeding outcomes across the first year postpartum also reinforces the importance of providing timely mother-centered support in the hospital and community to help women enjoy the early breastfeeding experience.

Maternal emotions during infant feeding appear to be predictive of breastfeeding outcomes, and not just reflective of an easy breastfeeding experience. Models controlled for numerous factors known to predict early breastfeeding cessation, including early breastfeeding problems, professional lactation support, prenatal depression scores, social support, birth trauma, and concurrent negative emotions during feeding; nevertheless, we found a predictive effect of positive maternal emotions on exclusive breast milk feeding and a better maternal experience of breastfeeding. The lack of significant modification of our findings by prenatal psychopathology or infant feeding status at two months suggests that the experiential and relational aspects of infant feeding may yield benefits regardless of early postpartum challenges. Healthcare providers and peer supporters should address the maternal emotional experience of infant feeding regardless of infant feeding method, given the potential benefits for both postpartum mental

health (Chapter 2) and overall maternal satisfaction with breastfeeding, especially the maternal enjoyment/role attainment and lifestyle/maternal body image dimensions.

Our findings should be interpreted in the context of study limitations. Subjects must have intended to breastfeed at least two months to participate in the parent study; as a result, they were more highly motivated to breastfeed than the general population. This study oversampled women at risk for postpartum psychopathology and comprised predominantly Non-Hispanic White, partnered, and highly educated women. Future research on positive emotions during infant feeding should be conducted in diverse populations, especially among underrepresented minority women and groups with lower breastfeeding intentions.

Selection into our analysis based on breast milk feeding status at two months may have biased our findings due to immortal person time, as the women who remain in the sample were "immortal" because they could not have been included if they had not continued breast feeding at two months. We assessed the likelihood of immortal person time bias in our results by conducting two sensitivity analyses using a measure of positive feelings about breastfeeding in the first week postpartum. When we changed only the exposure but kept the sample restricted to those breast milk feeding at two months, results were similar and more precise, suggesting positive maternal emotions at both one week and two months are predictive of longer term breastfeeding outcomes. Similarly, when we changed both the exposure and the sample, by exploring the association with breastfeeding outcomes in the larger sample of women breast milk feeding at one week, we also found similar results, suggesting no significant bias due to selection in our primary analysis.

Self-report measures used in analyses may have led to measurement bias, especially to the extent that affective responses were influenced by concurrent depression or anxiety.

However, we did not observe modification of our results by baseline psychopathology, which was indexed by a structured clinical interview for diagnosis. The mDES has not been used previously to assess positive emotions during infant feeding. However, the mDES has been shown to have a high internal reliability in other contexts (Cohn et al., 2009; Fredrickson et al., 2008), and our confirmatory factor analysis suggested that the 10 positive emotions best correlated with a single factor with roughly equal factor loadings for each item (Appendix Figure 1.1.1). While sensitivity analyses used a measure of positive feelings that has not been well validated, the results were similar to models using the mDES exposure, suggesting that both tools were capturing similar constructs.

Residual confounding may bias our results. We used a DAG to identify causal and non-causal paths between our exposure and outcomes of interest (Appendix 3.1), and used online software to identify the minimally sufficient adjustment set of confounders to adjust for in models (Dagitty, version 2.3). Future studies should build upon or alter our theoretical model using new evidence to ensure the appropriateness of the model and to justify using an appropriate set of confounders. Unmeasured confounding is reduced in these analyses due to breadth of data collected over time on study subjects and the minor amount of missingness.

Despite these limitations, our study has several strengths. To our knowledge, this is the first study to apply the broaden-and-build theory of positive emotions as a framework for research on the maternal experience of breastfeeding. While the mDES has not been previously used in the context of infant feeding, it has been validated across numerous contexts (Cohn et al., 2009; Fredrickson et al., 2008) and our factor analysis confirmed the positive emotions subscale best represented one coherent construct in relation to maternal emotions during feeding. Future studies would benefit from exploring the emotional experience of breastfeeding by applying this

tool at various timepoints across the breastfeeding experience to clarify temporal dynamics of positive emotions. Our study also collected extensive longitudinal data on infant feeding and maternal and infant characteristics across the postpartum, addressing some limitations of previous correlational and cross-sectional research on positive emotions (Lyubomirsky et al., 2005).

Conclusion

The maternal emotional experience of infant feeding and associated maternal and infant outcomes have not yet been rigorously researched. According to the broaden-and-build theory of positive emotions, experiences of positive emotions trigger upward spirals that improve well-being (Fredrickson, 2004). Our study provides preliminary evidence for an association between maternal positive emotions during breastfeeding and improved duration of exclusive breast milk feeding and overall maternal breastfeeding experience. These results can inform future mother-centered interventions and policies to support the quality of the breastfeeding experience and to improve maternal and infant health.

CHAPTER 4 – CONCULSIONS AND FUTURE DIRECTIONS

Conclusions

We found that positive emotions during infant feeding are associated with maternal mental health and breastfeeding outcomes across the first year postpartum. In chapter two, we used mixed effects models to estimate the association between positive emotions during infant feeding at two months and depression and anxiety outcomes at 2, 6, and 12 months. We found that higher positive emotions were associated with significantly fewer depression symptoms and lower odds of clinical depression among women without an active diagnosis of clinical depression during pregnancy. On the other hand, women with clinical anxiety in pregnancy who experienced higher positive emotions during feeding had significantly fewer postpartum anxiety symptoms and lower odds of clinically significant anxiety. Women with prenatal anxiety who neverthess enjoy the experience of infant feeding may benefit from anxiolytic effects of oxytocin during breastfeeding and mother-infant interaction (S. Kim et al., 2014; M. Newton & Newton, 1948; Niwayama et al., 2017; Stuebe et al., 2013b).

In chapter three, we used Cox proportional hazards regression to explore the association between positive emotions during breastfeeding at two months and time to cessation of any and exclusive breast milk feeding. We also used linear regression to test the association between positive emotions at two months and the overall maternal breastfeeding experience reported at 12 months. We repeated analyses to test the association between an earlier measure of maternal feelings about breastfeeding in the first week and all outcomes. Findings suggest that positive emotions are significantly associated with a longer time to cessation of exclusive breast milk

feeding and with a better overall maternal breastfeeding experience. We found no significant association between positive emotions at two months and time to any breast milk feeding cessation. When we repeated analyses using a measure of positive feelings about breastfeeding in the first week postpartum, positive feelings about breastfeeding in the first week predicted significantly longer time to any and exclusive breast milk feeding cessation and a better overall breastfeeding experience reported at 12 months.

Several general conclusions can be made from this preliminary work. First, positive emotions experienced during infant feeding are associated with outcomes independent of baseline personality or trait affect. Positive emotions experienced during feeding at two months were inversely associated with postpartum depression symptoms in the overall sample, even controlling for baseline depression scores and concurrent negative emotions during feeding. While the association between positive emotions and postpartum depression outcomes was stronger when women were not clinically depressed in pregnancy, the association between positive emotions and postpartum anxiety outcomes was stronger where women were diagnosed with clinical anxiety in pregnancy. Additionally, when we ran our models using a measure of positive feelings about breastfeeding in the first week, the association with breastfeeding outcomes was significant across the whole sample with no modification by baseline psychopathology or infant feeding method. These results suggest that maternal affective experience of breastfeeding may be a modifiable factor to improve both mental health and breastfeeding outcomes.

Second, both positive feelings about breastfeeding in the first week postpartum and positive emotions during feeding at two months were predictive of breastfeeding outcomes across the first year postpartum. The association between maternal emotions in the first week

postpartum and long-term breastfeeding outcomes highlights the importance of supporting the experiential aspects of early feeding through maternity practices that are mother-centered. A parallel approach to the feminist birth reform movement that has focused on empowering women to exercise autonomy over birthing decisions might be useful in the context of infant feeding (Mathews & Zadak, 1991); this approach could encourage more nuanced and collaborative discussions of women's goals, attitudes, and constraints in order to provide support for a positive and embodied breastfeeding experience (Young, 2005). We found that the experiential component of infant feeding was associated with the mother's overall satisfaction with the breastfeeding experience at 12 months, regardless of her breast milk feeding status. By supporting the maternal experience of infant feeding, healthcare providers and public health professionals may increase the likelihood that a mother who weans before she planned nevertheless has a positive experience.

Finally, research on the benefits of positive emotions during infant feeding is not meant to burden individual mothers with the responsibility for their own mental health and breastfeeding success while ignoring structural barriers that limit breastfeeding and stigmatize mental health treatment. However, the maternal emotional experience may be an important and potentially modifiable factor in postpartum mental health and breastfeeding that could be better addressed through changes in hospital, workplace, and community support for new mothers. Future research should explore maternal emotions across the infant feeding trajectory, using a social determinants of health framework to develop appropriate programs and policies to support the experiential process of infant feeding.

Strengths

This study used extensive longitudinal data collected from the third trimester of pregnancy through 12 months postpartum with little missingness or loss to follow up. These features of our data address many of the limitations of previous correlational research on positive emotions (Lyubomirsky et al., 2005) and perinatal mental health and breastfeeding (Dias & Figueiredo, 2014). The ability to control for prenatal depression and anxiety and to explore modification of our results by baseline psychopathology allowed us to assess the role of positive emotions on later outcomes unconfounded by baseline characteristics. For Aim 1, depression and anxiety outcomes were measured concurrently with the exposure only at two months, and similar results were found when using 6- and 12-month outcomes alone (see Appendix 2.2). For Aim 2, temporality between the exposure and outcome was preserved as all breast milk-feeding outcomes were measured following the two-month exposure.

Public health campaigns have primarily focused on helping women reach measurable breastfeeding duration and exclusivity targets, leaving the emotional experience of breastfeeding and its associated potential benefits under-explored (Auerbach, 1991; Benoit, Goldberg, & Campbell-Yeo, 2016). Positive emotions have also been underresearched compared with negative emotions due to a lack of theoretical frameworks and a primary focus on psychopathology (Fredrickson, 1998). We used an interdisciplinary approach to a novel research question by applying the broaden-and-build theory of positive emotions to a new and understudied population. Evidence from attachment theory aligns with the broaden-and-build theory, suggesting that early experiences of love from a caregiver allow an infant to securely pursue interest-inspired exploration (Bowlby, 1989), which is associated with the subsequent development of cognitive and social resources (Matas et al., 1978; Sroufe, 2005). However,

attachment theory has generally explored the benefits of postpartum experiences on infant outcomes. Our findings support the importance of targeting the mother-infant feeding and relational experience to improve maternal mental health and breastfeeding satisfaction. The broaden-and-build theory of positive emotions provides a framework for exploring resources accrued and health outcomes associated with maternal emotions during the perinatal period.

Limitations

This study was conducted in a population of pregnant women who planned to breastfeed at least two months. Nearly 60% of the sample was still any breast milk feeding at 12 months, well above national average of 33.7% (Centers for Disease Control and Prevention, 2017). Additionally, we oversampled women at high risk for postpartum depression and anxiety. While these characteristics improved our power to compare longer-term breastfeeding outcomes and allowed us to explore modification by baseline psychopathology, the emotional experience of infant feeding and its associated benefits may be different in the broader population. Additionally, there was evidence of floor and ceiling effects limiting the variation in the mental health and breastfeeding outcome estimates of our study sample. Many low risk women had consistently low BDI-II and STAI scores across the study follow-up, while many prenatally depressed or anxious women had consistently elevated scores (see Appendix 2.2).

Self-report measures could contribute to measurement error. While a diagnostic interview was used at baseline to assign women to risk categories for postpartum depression and anxiety, we use self-report measures of positive emotions during feeding, depression and anxiety outcome scores, and breastfeeding practices. However, BDI-II and STAI state anxiety tools have been validated in postpartum populations (Meades & Ayers, 2011; Vieira Da Silva Magalhães et al., 2008). The cutoff used for clinical anxiety may have been too high to detect more common

subsyndromal generalized anxiety symptoms (Wenzel et al., 2003); future research should explore the sensitivity and specificity of different tools for measuring postpartum anxiety symptoms in diverse samples. Maternal recall of breastfeeding practice has been shown to be valid and reliable, especially when recalled after only a short period (Li et al., 2005). In our study, infant feeding practices were recalled over the previous week to improve accuracy. We conducted a confirmatory factor analysis for the mDES exposure instrument that indicated the 10 positive emotions best correlate with a single factor with roughly equal factor loadings for all items (CFI=0.9530) (see Appendix Figure 1.1.1). Because the mDES was first asked at two months postpartum, after some women had already stopped any or exclusive breastfeeding, we repeated breastfeeding outcome analyses with an earlier measure of maternal feelings about breastfeeding in the first week and conducted sensitivity analyses for both aims to explore the role of infant feeding status and psychotropic medication use on outcomes. Additionally, the MBFES was only asked at 12 months, so we are limited to understanding women's overall experience of breastfeeding only after the first postpartum year.

Due to power constraints, we were unable to explore modification by race/ethnicity or socioeconomic status. While racism has a well-established effect on breastfeeding opportunities and outcomes (Li & Grummer-Strawn, 2002), and minority populations experience a high prevalence postpartum depression and anxiety (Beeghly et al., 2003; Zayas, Cunningham, McKee, & Jankowski, 2002), the small total sample size and proportion of participants who are women of color or low income prevented us from quantifying associations between positive emotions and outcomes within these groups. Future research should be conducted in diverse samples to better understand how maternal emotional experiences of infant feeding and associated outcomes may vary by race/ethnicity and socioeconomic status.

Future Directions

National public health recommendations allude to maternal desire as a factor that should guide breastfeeding duration. However, this component of breastfeeding has not yet been rigorously investigated by researchers, targeted by breastfeeding promotion programs, or supported by policymakers focused on quantitative targets for infant breast milk consumption. For example, Healthy People 2020 objectives aim to increase the proportion of infants who are breastfed (US Department of Health and Human Services, 2012). The Affordable Care Act's workplace protections for nusing mothers reinforce this value on infant consumption of breast milk by requiring a reasonable break time and private space for breast milk expression only for one year after the child's birth; this policy aligns with national objectives regarding infant consumption, ignoring the relational or emotional benefits that may continue long after the first year (Hilliard, 2017; Kozhimannil, Jou, Gjerdingen, & McGovern, 2016). Health care providers rarely discuss with mothers the lived experience of breastfeeding as a "dynamic, relational experience that changes over time" (Dykes, 2006). A woman-centered approach that values the maternal emotional experience of breastfeeding is needed in future research, health care, and national policy.

A variety of research tools could be used to probe experiences of maternal emotions during infant feeding and associated outcomes. Qualitative research using a feminist perspective could explore how maternal emotions during feeding vary across the postpartum, considering how relational and embodied processes change over time and affect infant feeding decision-making. This research should be prioritized among women with risk factors for both early weaning and postpartum psychopathology, such as women who have experienced childhood trauma, birth trauma, or substance use disorder, to better understand opportunities for

intervention and policy that could improve multiple maternal outcomes. Quantitative methods are needed to address limitations of retrospective data regarding affective experiences, especially where psychopathology common to the perinatal period may influence maternal report. Innovative technologies for collecting ecological momentary assessment (EMA) data have been employed to obtain real-time measures of individuals' behaviors and emotions, reducing the impact of recall bias in conventional retrospective approaches (Shiffman, Stone, & Hufford, 2008). These EMA data collection methods have not yet been applied to improve our understanding of the temporal dynamics of maternal experiences in the perinatal period. EMA tools could be used to collect ambulatory data on women's emotional experiences across the period of parenting, as the associated rewards and demands may change across the postpartum.

Potential biological mechanisms linking experiences of positive emotions and mental health and breastfeeding outcomes should be further researched. Oxytocin has been identified as a potential mechanism linking positive feelings during breastfeeding and later maternal mood (Stuebe et al., 2013a). Oxytocin levels rise sharply at birth and are hypothesized to stimulate critical maternal care behaviors (Ruth Feldman, Aron, Zagoory-Sharon, & Levine, 2007; Levine, Zagoory-Sharon, Feldman, & Weller, 2007). Women who experience positive emotions during infant feeding may benefit from reduced stress reactivity and increased mother-infant bonding behavior associated with oxytocin (Bell, Erickson, & Carter, 2014; R Feldman, Gordon, Schneiderman, Weisman, & Zagoory-Sharon, 2010). Maternal oxytocin levels were collected throughout the MMI study at baseline and 2, 6, and 12 months postpartum; oxytocin profiles could be analyzed to complement our preliminary findings with biomarker data.

We found that women with low positive emotions during feeding at two months were significantly more likely to have also had a cesarean birth, a more traumatic birth experience,

and no skin-to-skin with the infant in the first hour after birth. Given the role of the early maternal breastfeeding experience as a modifiable factor for improving long-term breastfeeding outcomes, mothers should be supported to process difficult birth experiences and cope with early breastfeeding challenges through shared decision-making with their healthcare providers. In addition to implementing BFHI maternity practices associated with improved breastfeeding duration (Kramer et al., 2001; Merewood, 2005; Munn et al., 2016) and maternal breastfeeding satisfaction (Hongo et al., 2015), health care providers can reframe discussions about breastfeeding to incorporate the maternal experience and associated benefits. Our findings that positive emotions during feeding are associated with lower postpartum depression among low risk women, lower postpartum anxiety among high risk women, and longer breastfeeding exclusivity and satisfaction overall underscore the need for maternal-driven discussions about breastfeeding that may vary based on a mother's mental health and lived experiences. This approach would address the limitations of a universal infant-focused message of "breast is best" that fails to account for diverse maternal experiences and constraints on infant feeding choices (Benoit et al., 2016; Wolf, 2007). Collaborative discussions about the benefits of breastfeeding could be broadened to include the relational and experiential aspects that may improve maternal mental health and breastfeeding outcomes.

Positive psychology interventions developed for the perinatal period could complement childbirth education and breastfeeding classes with a focus on the maternal experience. Meditation-based strategies that direct attention to experiences of positive emotions have shown promising results for improving psychological well-being in the perinatal period (Duncan & Bardacke, 2010; Perez-Blasco, Viguer, & Rodrigo, 2013; Vieten & Astin, 2008). Positive psychology practices to elicit gratitude have led to increased prosocial responses and

strengthened social bonds (Algoe, Haidt, & Gable, 2008; Tsang, 2006). Future interventions could adapt these strategies for the perinatal period, possibly teaching practices that could be used during infant feeding to better support the maternal experience.

Policies to reduce inequities in breastfeeding rates and associated maternal and infant health outcomes should recognize the value of the maternal emotional experience. Given that maternal experiences of breastfeeding vary by socioeconomic circumstances (E. Burns et al., 2010), policies should address the embodied experience of breastfeeding by ensuring mothers have support to meet their needs regardless of income or race/ethnicity. While return to work was not associated with lower positive emotions during feeding in our sample, paid maternity leave is needed to ensure socioeconomic status is not a barrier to positive emotional experiences of feeding and their associated benefits. Workplace policies should be available to mothers as long as they desire to breastfeed their baby without restriction by infant age. Maternally focused policies to address race-based discrimination in healthcare (Thomas, 2018) and improve access to affordable breastfeeding-friendly child care (J. Kim & Gallien, 2016) could also improve equity in access to the benefits of positive breastfeeding experiences.

APPENDIX 1.1: FACTOR ANALYSIS OF POSITIVE EMOTIONS DURING INFANT FEEDING

Because this is the first time the mDES is applied in the context of infant feeding, we conducted a confirmatory factor analysis that indicated the 10 positive emotions assessed by this instrument best correlate with a single factor with roughly equal factor loadings for all items (CFI=0.9530) (see Figure 1.1.1 below).

Figure 1.1.1 Confirmatory factor Analysis of modified Differential Emotions Scale to assess positive emotions during infant feeding at two months

Preliminary Eigenvalues: Total = 5.15584927 Average = 0.51558493				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	5.11841249	4.81574371	0.9927	0.9927
2	0.30266879	0.10020604	0.0587	1.0514
3	0.20246275	0.13427354	0.0393	1.0907
4	0.06818921	0.04574253	0.0132	1.1039
5	0.02244668	0.05245780	0.0044	1.1083
6	-.03001112	0.02726728	-0.0058	1.1025
7	-.05727840	0.05466558	-0.0111	1.0914
8	-.11194398	0.04131578	-0.0217	1.0696
9	-.15325976	0.05257762	-0.0297	1.0399
10	-.20583739		-0.0399	1.0000

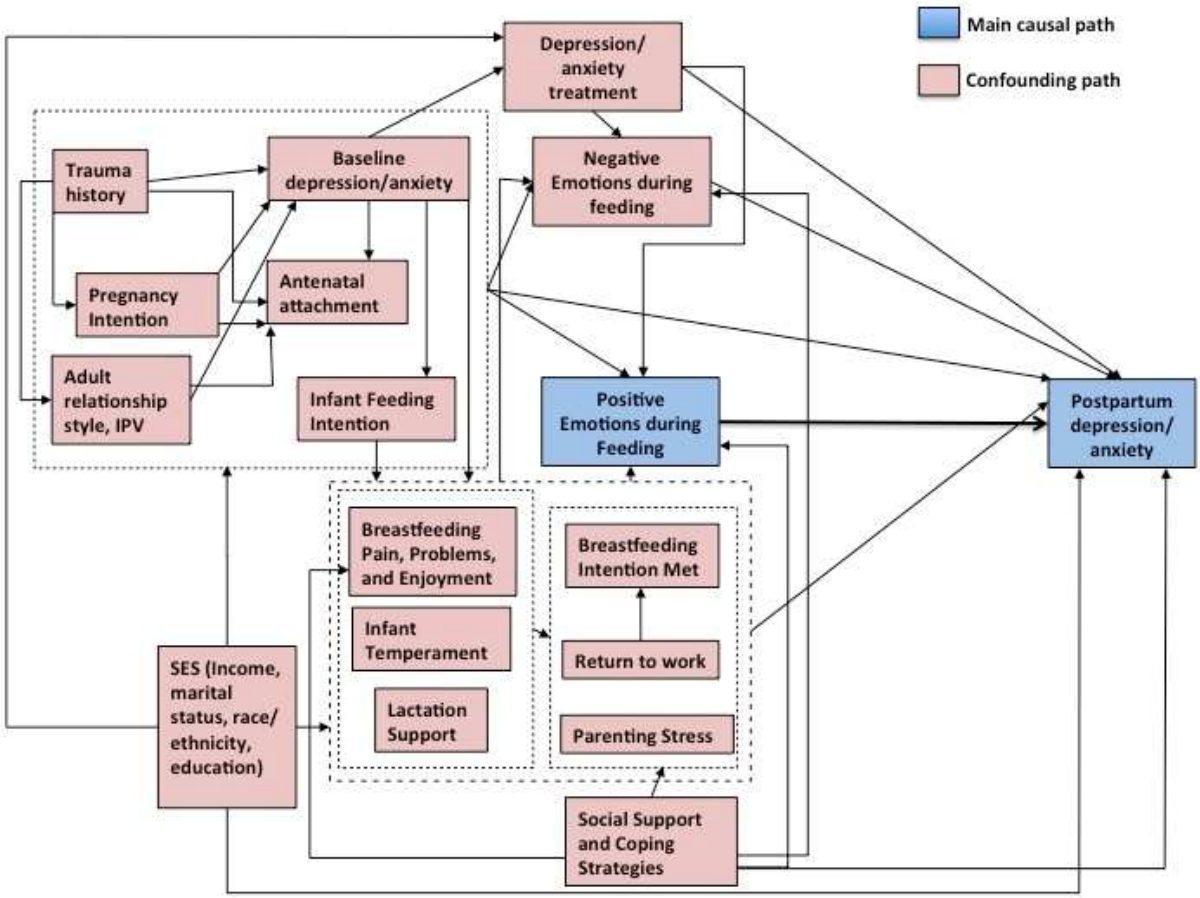
Factor Pattern		
	Factor1	**Factor2**
Amusement	0.58453	0.24662
Awe	0.65047	-0.04677
Gratitude	0.71592	0.09201
Hope	0.76496	0.13878
Inspiration	0.77829	0.10729
Interest	0.75680	0.23442
Joy	0.79512	-0.02925
Love	0.68231	-0.17814
Pride	0.70109	-0.08125
Contentment	0.72944	-0.47285

APPENDIX 2.1: ADDITIONAL AIM 1 ANALYSES

Information found in this appendix was not included in the main dissertation either because it was not part of a priori aims or because it provides supplementary information not critical to the interpretation of the primary results. This section of the appendix provides additional information on Aim 1 model building and statistical analyses.

Directed acyclic graphs (DAGs) are tools used to represent causal relationships between the exposure, outcome, and covariates as hypothesized based on the literature and subject matter expertise of the investigators. Graphs use nodes (labeled as variables) connected by lines with single arrowheads and no loops. This tool allows the investigators to be transparent about assumed causal pathways and limitations of estimating these effects in actual data (Greenland et al., 1999). This DAG conceptualizes the hypothesized relationships between positive emotions during infant feeding and postpartum mental health based on the literature and subject matter expertise of the co-authors (Figure 2.1.1).

Figure 2.1.1: Directed Acyclic Graph (DAG) of the relationship between positive emotions during infant feeding at two months and postpartum depression/anxiety outcomes



For parenting stress, childhood trauma, infant temperament, and social support measures, we explored the correlation between subscale scores and the total score and crude associations with depression/anxiety outcomes. Because subscores were highly correlated with the total scores and total scores were associated with the outcomes, we opted to use the total scores for consideration as confounders/modifiers in our analyses.

Collinearity was explored between variables in the model by calculating the standardized mean difference between continuous variables and different levels of dichotomous or polytomous variables, pearson correlation coefficients (ρ) between continuous variables, and pairwise odds ratios between dichotomous/polytomous variables. Collinearity was considered problematic where it led to model instability with inflated estimates/standard errors. Psychiatric treatment between baseline and two months postpartum was highly collinear with baseline risk for postpartum depression/anxiety (OR=12.6), as 42 of the 45 women in treatment were considered high risk. Prenatal depression or anxiety scores were used to control for baseline severity instead of treatment, and a sensitivity analysis excluded mothers using psychotropic medications by the time of exposure assessment. Positive and negative emotions during breastfeeding were not highly collinear; while inversely correlated ($\rho = -0.21, p = 0.0061$), the presence of positive emotions during feeding does not indicate the absence of negative emotions. Parenting stress and positive emotions during infant feeding were more strongly inversely correlated: ($\rho = -0.54,\ p < 0.001$), and when included in the model parenting stress caused the estimate of effect for positive emotions to flip to the other side of the null (becoming slightly positive). We chose a minimally sufficient adjustment set that did not include parenting stress due to this model estimate instability. Further research should explore the relationship between maternal emotions during infant feeding and parenting stress, as they may be capturing

related constructs. Finally, while return to work by the time of exposure assessment was included in our minimally sufficient covariate set, return to work was unexpectedly associated with slightly higher positive emotions during feeding in our sample. This may be due to the composition of our sample, in which a third of women were clinically diagnosed with prenatal depression/anxiety in pregnancy. Baseline depression and anxiety scores were higher among those returning to work by two months (nearly significant differences: p=0.06 for depression scores and p=0.09 for anxiety scores). Additionally, return to work by two months was not significantly associated with positive emotions at two months and timing of return to work was not correlated with positive emotions ($\rho = 0.003, p = 0.97$). We removed return to work from our models, but future research in the broader population should explore the role of postpartum timing of return to work outside the home on the maternal experience of infant feeding and mental health outcomes.

While depression/anxiety outcomes where slightly skewed toward lower scores, model residuals were normally distributed with few extreme outliers (one excluded due to a priori criteria). The random scatter around the zero reference line indicated no problems with the random effects covariance structure (see Figure 2.1.2 below).

Figure 2.1.2 Scaled residuals for depression and anxiety models indicating no problems with the random effects covariance structure

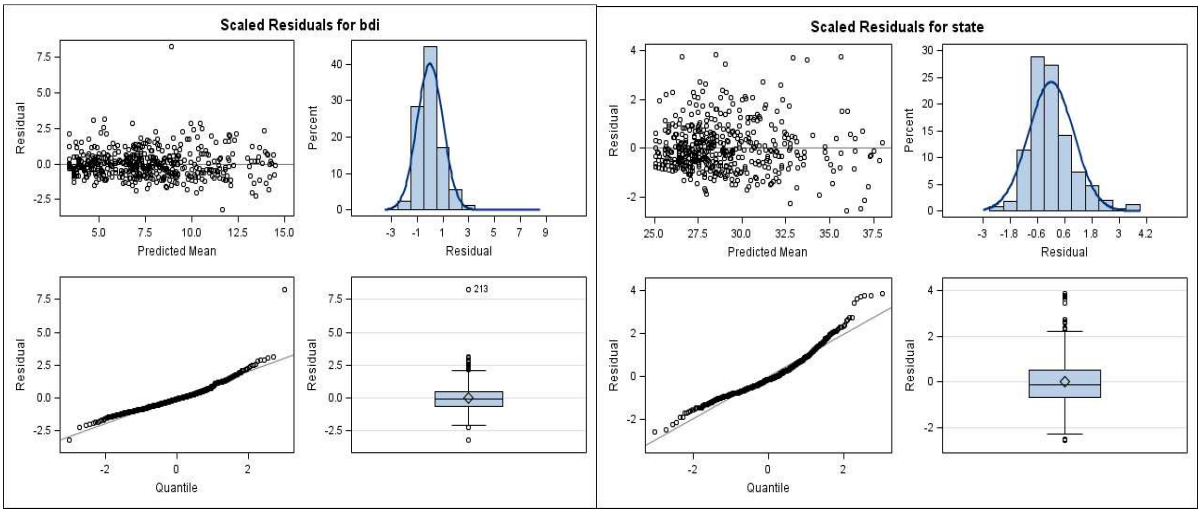


Table 2.1.1: Number of women meeting thresholds for postpartum depression/anxiety				
		N (%) experiencing outcome		
Clinically significant depression (BDI-II ≥14)		*Month 2*	*Month 6*	*Month 12*
Overall	164	27 (16.5)	25 (15.2)	27 (16.5)
No prenatal depression	125	16 (12.8)	17 (13.6)	15 (12.0)
Prenatal depression diagnosis	39	11 (28.2)	8 (20.5)	12 (30.8)
Clinically significant anxiety (STAI-S >40)				
Overall	164	12 (7.3)	8 (4.9)	16 (9.8)
No prenatal anxiety	121	9 (7.4)	5 (4.1)	8 (6.6)
Prenatal anxiety diagnosis	43	3 (7.0)	3 (7.0)	8 (18.6)

To explore potential floor and ceiling effects, we examined the number of women meeting thresholds for clinically significant postpartum depression **(**BDI-II ≥14) and anxiety symptoms (STAI-S>40) by the baseline psychopathology modifier used in Chapter 2 analyses. Table 2.1.1 indicates that women in both groups of women diagnosed with clinical depression or anxiety via SCID and groups without diagnosed disorders at baseline met thresholds for postpartum depression and anxiety at months 2, 6, and 12. There was also variability in meeting a clinically significant threshold for depression/anxiety outcomes using the BDI-II and STAI-S. Among those reaching the threshold for postpartum depression at 2, 6, or 12 months, 30 mothers experienced depression at only one time point, 10 at two time points, and nine mothers at all three time points. Among those reaching the threshold for postpartum anxiety at 2, 6, or 12 months, 17 mothers experienced anxiety at only one time point, seven at two time points, and only two mothers at all three time points.

In addition to the outcomes discussed in Chapter 2, we examined change scores for depression (BDI-II) and state anxiety (STAI-S) between months 2 and 6 and months 6 and 12; however, the variability of change scores was too small to permit us to detect associations with positive emotions during infant feeding.

We decided a priori not to use Edinburgh Postnatal Depression Scale (EPDS) scores for depression/anxiety outcomes, because women reported monthly EPDS scores and may have become habituated to this tool. In exploratory data analyses, we confirmed that there was more variability in BDI-II and STAI-S scores, as these instruments were used at only three timepoints across the first postpartum year.

The best functional form of each continuous variable in our models was considered by comparing model fit using AIC/BIC. First, models including a random intercept alone or both a random intercept and slope were compared. After choosing the appropriate random effects and comparing variance components and unstructured covariance structures, linear and indicator forms of time were compared for model fit. For continuous depression and anxiety models, the linear form of time with a variance components covariance structure, random intercept, and random slope had the lowest AIC/BIC. For binary outcomes, the linear form of time with an unstructured covariance structure and random intercept had the best model fit.

The functional forms of continuous positive emotions during feeding and continuous confounders/modifiers were explored by comparing linear and quadratic forms; variables dichotomized at the median (2.9), 2, and 2.5; as tertiles; and at three-knot splines. Positive emotions during feeding were also categorized by each unit on the 4-item scale (0-1, >1-2, >2-3, 3-4). Functional form assessment showed best-fitting relationship between BDI-II and STAI-S outcomes was best with a continuous positive emotions variable and the second best-fitting relationship was with a dichotomous variable at at >2.5 v <=2.5. In depression models, model fit was best with linear forms of baseline depression scores, social support at two months, and concurrent negative emotions. In anxiety models, linear forms of confounders social support, baseline anxiety scores, and concurrent negative emotions were selected based on model fit. All

models used maximum likelihood estimation to compare model fit statistics and were re-estimated using restricted maximum likelihood REML to appropriately estimate the appropriate covariance.

We also explored effect measure modification by negative emotion score, infant temperament score, number of early breastfeeding problems, meeting one's breastfeeding intention by two months, and moderate/severe childhood trauma experience. We estimated slopes and 95% CI for the estimate of positive emotions conditional on high v. low values (75% v. 25%) of continuous effect measure modifiers.

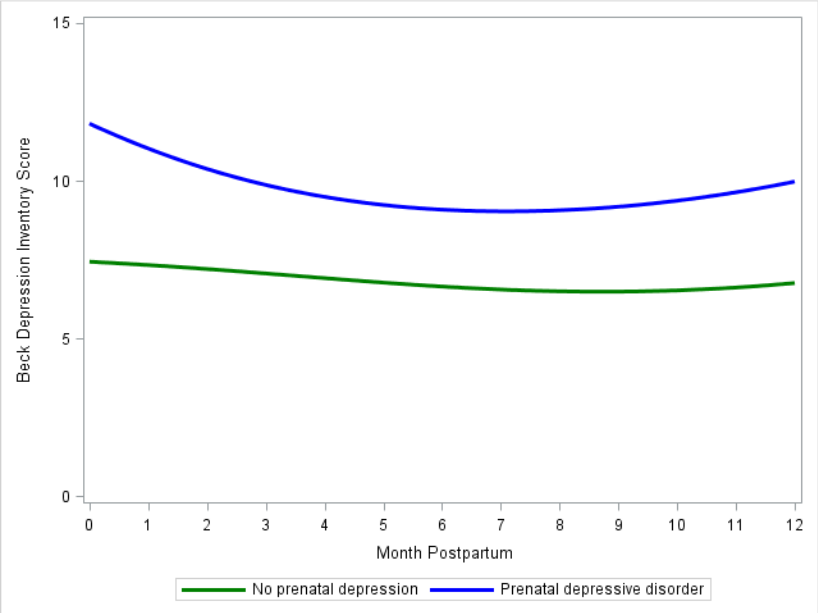
APPENDIX 2.2: ADDITIONAL AIM 1 RESULTS

Compared with our analytic sample, the 13 women excluded from the analysis (12 due to missing exposure data and one outlier) were more likely to be Non-Hispanic Black (30.8% v. 9.1%), unmarried (15.4% v. 9.1%), and multiparous (69.2% v. 45.7%); have a lower education level (23.1% v. 6.1%); have returned to work by two months postpartum (77.8% v. 29.9%); receive psychiatric treatment for depression/anxiety (83.3% v. 27.4%); and not have met their prenatal breastfeeding intention by two months postpartum (50.0% v. 32.3%).

Among the 32.9% of the sample at high risk for postpartum depression/anxiety based on an active depression or anxiety disorder in pregnancy, 51.9% experienced comorbid depression/anxiety, while 20.4% experienced active depression and 27.8% experienced active anxiety alone.

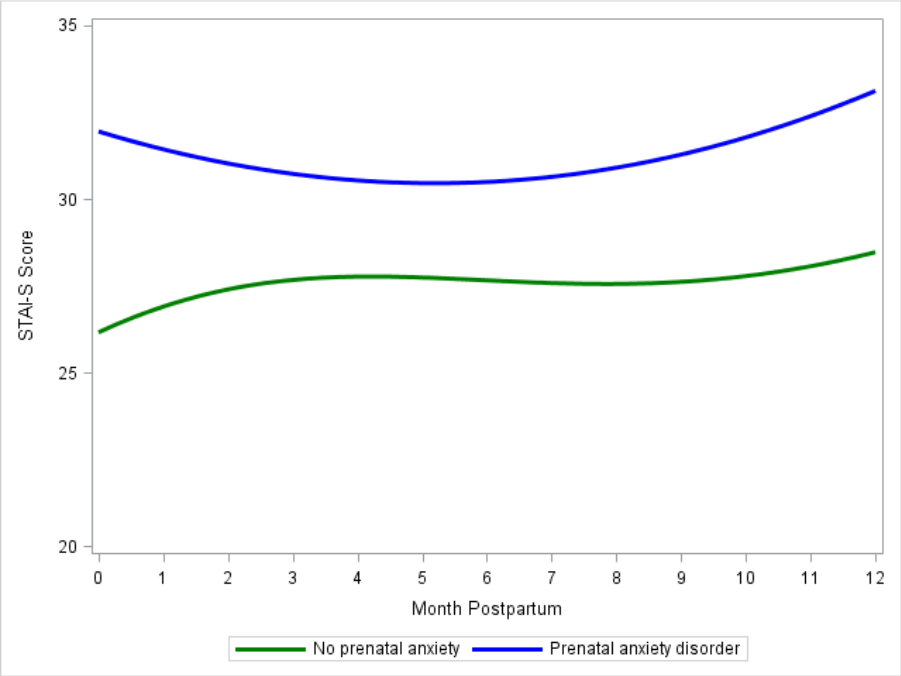
Mean depression (BDI-II) scores were highest in the third trimester of pregnancy, and decreased across the 12 months postpartum for both women with and without prenatal depression (see Figure 2.2.1 below).

Figure 2.2.1: Trajectories of BDI-II depression scores from the third trimester of pregnancy through 12 months postpartum, by presence or absence of a SCID-diagnosed prenatal depressive disorder



However, mean anxiety (STAI-S) scores increased from the third trimester to 12 months postpartum for women without prenatal anxiety, and they dropped slightly from pregnancy to six months and increased by month 12 among those with prenatal anxiety (see Figure 2.2.2 below).

Figure 2.2.2: Trajectories of STAI-S state anxiety scores from the third trimester of pregnancy through 12 months postpartum, by baseline risk for postpartum anxiety

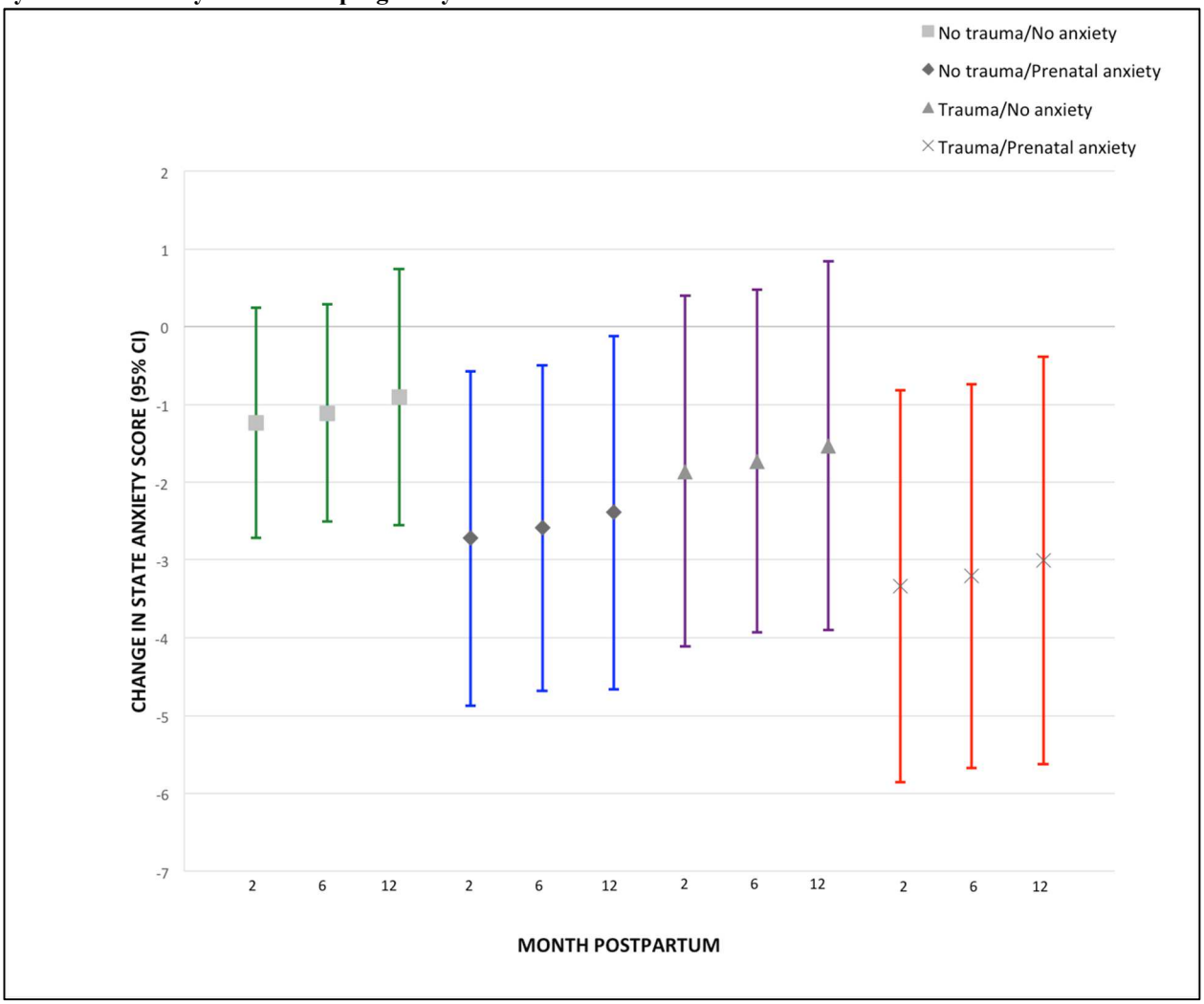


We explored modification of the association between positive emotions and postpartum depression/anxiety by women's baseline psychopathology defined both as presence or absence of clinical depression/anxiety during pregnancy via third trimester SCID (see results in Chapter 2) and by risk status for postpartum depression/anxiety, where "high risk" was indexed by a SCID-confirmed history of depression/anxiety or an active depressive/anxiety disorder in pregnancy. High versus low risk status did not significantly modify the effect of positive emotions on BDI-II depression scores (LRT=3, p=0.08), clinical depression scores (LRT=2.1, p=0.15), or clinical anxiety scores (LRT=0.7, p=0.40); therefore, we chose to present findings by presence or absence of clinical depression/anxiety during pregnancy.

We repeated analyses using only six- and 12-month outcomes, and found consistent results (albeit with wider confidence intervals due to fewer observations) reducing concerns regarding temporality.

In secondary analyses, only moderate/severe childhood trauma was found to significantly modify the association between positive emotions and anxiety scores (LRT=6.6, p=0.01), with the strongest effect of positive emotions on subsequent anxiety symptoms observed among women with both prenatal anxiety and moderate/severe childhood trauma (Figure 2.2.3). However, all stratified confidence intervals overlapped due to lack of power to consider multiple modifiers. Future research should explore differences by specific experiences of abuse or neglect.

Figure 2.2.3: Association between a one-point increase in positive emotions during infant feeding and STAI-S scores for anxiety adjusted for baseline anxiety scores, social support, and negative emotions during feeding, by baseline anxiety disorder in pregnancy and childhood trauma



Our results remained robust to sensitivity analyses testing both the exclusion of exclusive formula feeders and women taking psychotropic medications (see Appendix Table 2.2.1 below).

Table 2.2.1: Estimates of association between a one-unit increase in positive emotions during infant feeding at two months and postpartum depression and anxiety at 2, 6, and 12 months: Sensitivity analyses

		2 months	6 months	12 months	
Continuous depression outcome (BDI-II)[a]	**N**	*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*	*LRT (p-value)*
Overall Adjusted Model	164	**-0.96 (-1.74, -0.18)**	**-1.09 (-1.83, -0.35)**	**-1.29 (-2.42, -0.16)**	
Excluding exclusive formula feeders	150	**-1.36 (-2.16, -0.57)**	**-1.21 (-1.98, -0.43)**	-0.97 (-2.07, 0.14)	
Excluding medicated	130	**-1.04 (-1.92, -0.15)**	**-0.94 (-1.75, -0.12)**	-0.78 (-1.85, 0.29)	
By baseline psychopathology, adjusted model[b]					**6.0 (*p*=0.01)**
No active prenatal depression	125	**-1.41 (-2.33, -0.50)**	**-1.54 (-2.44, -0.64)**	**-1.74 (-3.01, -0.47)**	
Active prenatal depression diagnosis	39	-0.33 (-2.15, 1.48)	-0.46 (-2.27, 1.35)	-0.66 (-2.68, 1.36)	
Excluding exclusive formula feeders					**6.8 (*p*=0.01)**
No active prenatal depression	115	**-1.79 (-2.72, -0.86)**	**-1.63 (-2.56, -0.71)**	**-1.40 (-2.64, -0.15)**	
Active prenatal depression diagnosis	35	-0.53 (-2.44, 1.38)	-0.38 (-2.28, 1.53)	-0.14 (-2.21, 1.94)	
Excluding medicated					**9.2 (*p*=0.002)**
No active prenatal depression	118	**-1.56 (-2.54, -0.57)**	**-1.46 (-2.37, -0.54)**	**-1.30 (-2.43, -0.17)**	
Active prenatal depression diagnosis	12	0.76 (-2.86, 4.39)	0.87 (-2.74, 4.47)	1.02 (-2.64, 4.68)	
Clinically significant depression (BDI-II ≥14)[a]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*	
Overall Adjusted Model	164	0.55 (0.29, 1.06)	0.61 (0.37, 1.03)	0.72 (0.36, 1.42)	
Excluding exclusive formula feeders	150	**0.37 (0.17, 0.80)**	**0.46 (0.25, 0.86)**	0.65 (0.30, 1.42)	
Excluding medicated	130	0.54 (0.25, 1.19)	0.63 (0.34, 1.17)	0.78 (0.34, 1.80)	
By baseline psychopathology, adjusted model[b]					0.9 (*p*=0.35)
No active prenatal depression	125	**0.44 (0.21, 0.92)**	**0.48 (0.26, 0.90)**	0.57 (0.26, 1.22)	
Active prenatal depression diagnosis	39	0.67 (0.20, 2.19)	0.74 (0.24, 2.26)	0.87 (0.26, 2.89)	
Excluding exclusive formula feeders					1.0 (*p*=0.32)
No active prenatal depression	115	**0.28 (0.12, 0.69)**	**0.35 (0.17, 0.76)**	0.50 (0.20, 1.22)	
Active prenatal depression diagnosis	35	0.48 (0.12, 1.94)	0.60 (0.16, 2.24)	0.84 (0.21, 3.43)	
Excluding medicated					1.2 (*p*=0.27)
No active prenatal depression	118	**0.41 (0.17, 0.97)**	**0.48 (0.24, 0.97)**	0.50 (0.24, 1.47)	
Active prenatal depression diagnosis	12	1.25 (0.08, 18.88)	1.46 (0.10, 21.04)	1.83 (0.12, 27.95)	
Continuous anxiety outcome (STAI-S)[b]		*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*	
Overall Adjusted Model	164	-0.61 (-1.71, 0.63)	-1.02 (-2.64, 0.61)	-0.71 (-2.89, 1.48)	
Excluding exclusive formula feeders	150	-0.85 (-1.94, 0.24)	-0.47 (-1.44, 0.51)	0.10 (-1.26, 1.46)	
Excluding medicated	130	-0.56 (-1.78, 0.66)	-0.35 (-1.42, 1.35)	-0.04 (-1.44, 1.35)	

By baseline psychopathology, adjusted model[b]					**8.4 (*p*=0.004)**
No active prenatal anxiety	121	-0.93 (-2.29, 0.42)	-0.81 (-2.06, 0.45)	-0.61 (-2.14, 0.92)	
Active prenatal anxiety diagnosis	43	**-2.64 (-4.77, -0.50)**	**-2.51 (-4.58, -0.43)**	**-2.31 (-4.56, -0.06)**	
Excluding exclusive formula feeders					**7.4 (*p*=0.01)**
No active prenatal anxiety	115	-1.14 (-2.52, 0.24)	-0.76 (-2.04, 0.53)	-0.19 (-1.77, 1.40)	
Active prenatal anxiety diagnosis	35	**-2.66 (-4.99, -0.32)**	**-2.28 (-4.56, -0.01)**	-1.71 (-4.17, 0.76)	
Excluding medicated					**11.4 (*p*=0.001)**
No active prenatal anxiety	118	-0.79 (-2.24, 0.67)	-0.58 (-1.91, 0.75)	-0.27 (-1.88, 1.34)	
Active prenatal anxiety diagnosis	12	**-3.79 (-7.34, -0.23)**	**-3.58 (-7.09, -0.07)**	-3.27 (-6.89, 0.35)	
Clinically significant anxiety (STAI-S>40)[b]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*	
Overall Adjusted Model	164	0.64 (0.26, 1.60)	0.63 (0.31, 1.27)	0.60 (0.25, 1.44)	
Excluding exclusive formula feeders	150	0.88 (0.33, 2.39)	1.03 (0.48, 2.21)	1.31 (0.50, 3.43)	
Excluding medicated	130	1.18 (0.43, 3.28)	1.15 (0.52, 2.52)	1.10 (0.39, 3.07)	
By baseline psychopathology, adjusted model[b]					**10.0 (*p*=0.002)**
No active prenatal anxiety	121	1.53 (0.52, 4.53)	1.47 (0.59, 3.62)	1.37 (0.49, 3.85)	
Active prenatal anxiety diagnosis	43	0.32 (0.09, 1.14)	**0.30 (0.10, 0.96)**	**0.28 (0.06, 0.98)**	
Excluding exclusive formula feeders					**7.7 (*p*=0.01)**
No active prenatal anxiety	115	1.16 (0.36, 3.75)	1.34 (0.50, 3.58)	1.66 (0.54, 5.18)	
Active prenatal anxiety diagnosis	35	0.24 (0.06, 1.06)	0.38 (0.08, 1.06)	0.35 (0.08, 1.48)	
Excluding medicated					**7.7 (*p*=0.01)**
No active prenatal anxiety	118	1.52 (0.48, 4.86)	1.46 (0.57, 3.77)	1.38 (0.44, 4.39)	
Active prenatal anxiety diagnosis	12	0.11 (0.01, 1.04)	**0.10 (0.01, 0.92)**	**0.10 (0.01, 0.99)**	

When we excluded women not doing any breast milk feeding at two months, results were similar but less precise for continuous depression and anxiety score outcomes and slightly stronger and more precise for clinically significant depression and anxiety score outcomes. Excluding mothers taking psychotropic medications decreased precision for all estimates, though the effects did not differ greatly from the main analyses.

We also present main results by high (>2.5-4) versus low (0-2.5) positive emotions, which had the second most optimal model fit with depression and anxiety outcomes, to align with the presentation of Table 2.1 descriptive characteristics in Chapter 2.

Table 2.2.2 Estimates of association between high versus low positive emotions during infant feeding at 2 months and postpartum depression and anxiety outcomes at 2, 6, and 12 months

	N	2 months	6 months	12 months
Continuous depression outcome (BDI-II)[a]		*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*
Mean score (SD)		8.0 (5.4)	7.2 (5.5)	7.5 (7.0)
Crude Model	164	**-2.85 (-4.41, -1.28)**	**-2.90 (-4.44, -1.35)**	**-2.98 (-5.16, -0.79)**
Overall Adjusted Model	164	**-1.53 (-2.87, -0.20)**	**-1.59 (-2.86, -0.32)**	-1.67 (-3.60, 0.26)
By baseline psychopathology, adjusted model[b]				
No prenatal depression	125	**-2.36 (-3.98, -0.73)**	**-2.41 (-4.02, -0.84)**	**-2.49 (-4.71, -0.27)**
Prenatal depression diagnosis	39	-0.41 (-3.09, 2.27)	-0.46 (-3.14, 2.21)	-0.54 (-3.62, 2.53)
Clinically significant depression (BDI-II ≥14)[a]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*
N (%)		27 (16.5)	25 (15.2)	27 (16.5)
Crude Model	164	**0.20 (0.06, 0.68)**	**0.25 (0.09, 0.69)**	0.36 (0.10, 1.28)
Overall Adjusted Model	164	0.38 (0.12, 1.16)	0.48 (0.20, 1.16)	0.70 (0.22, 2.23)
By baseline psychopathology, adjusted model[b]				
No prenatal depression	125	**0.20 (0.06, 0.76)**	**0.26 (0.09, 0.78)**	0.37 (0.10, 1.42)
Prenatal depression diagnosis	39	0.80 (0.14, 4.60)	1.01 (0.20, 5.09)	1.45 (0.24, 8.76)
Continuous anxiety outcome (STAI-S)[c]		*Beta (95% CI)*	*Beta (95% CI)*	*Beta (95% CI)*
Mean score (SD)		28.6 (7.4)	28.2 (6.5)	29.7 (8.0)
Crude Model	164	**-3.15 (-5.23, -1.08)**	**-2.94 (-4.85, -1.04)**	**-2.63 (-5.08, -0.19)**
Overall Adjusted Model	164	-1.22 (-3.08, 0.63)	-1.02 (-2.64, 0.61)	-0.71 (-2.89, 1.48)
By baseline psychopathology, adjusted model[b]				
No prenatal anxiety	121	-1.93 (-2.29, 0.42)	-0.81 (-2.06, 0.45)	-0.61 (-2.14, 0.92)
Prenatal anxiety diagnosis	43	**-2.64 (-4.77, -0.50)**	**-2.51 (-4.58, -0.43)**	**-2.31 (-4.56, -0.06)**
Clinically significant anxiety (STAI-S >40)[c]		*Odds (95% CI)*	*Odds (95% CI)*	*Odds (95% CI)*
N (%)		12 (7.3)	8 (4.9)	16 (9.8)
Crude Model	164	0.29 (0.06, 1.38)	0.41 (0.13, 1.35)	0.70 (0.16, 3.06)
Overall Adjusted Model	164	0.68 (0.15, 3.11)	0.96 (0.30, 3.05)	1.61 (0.37, 7.01)
By baseline psychopathology, adjusted model[b]				
No prenatal anxiety	121	1.18 (0.20, 6.89)	1.66 (0.38, 7.20)	2.76 (0.49, 15.57)
Prenatal anxiety diagnosis	43	**0.17 (0.01, 0.56)**	**0.07 (0.01, 0.63)**	0.12 (0.01, 1.23)

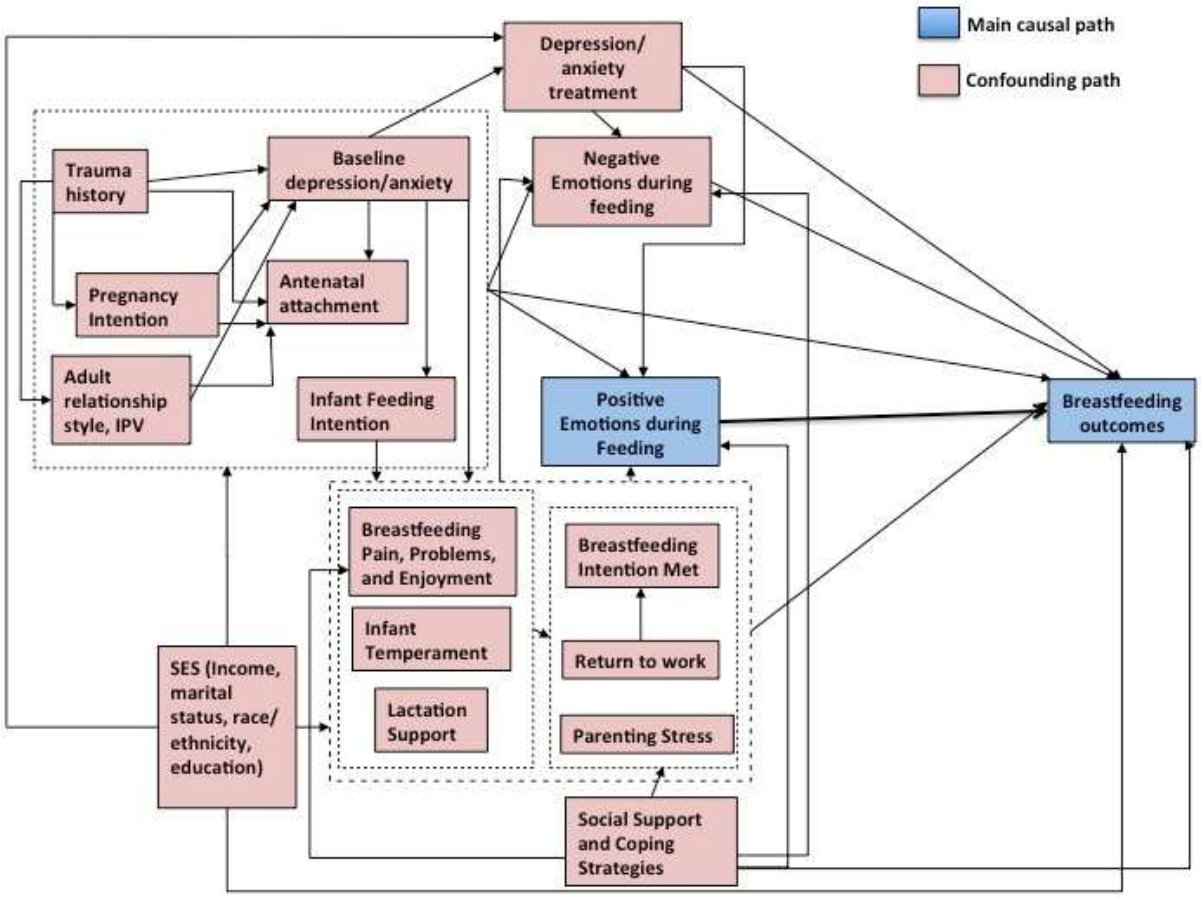
Mixed models were used to estimate the crude and multivariable associations. Linear mixed models for continuous depression/anxiety outcomes included a random intercept to allow baseline depression/anxiety scores to differ among participants, a random effect for time to account for interperson differences in scores over time, and a variance components covariance structure to account for intraperson correlations across repeat measures. For binary outcomes, generalized linear mixed models included a random intercept and unstructured covariance structure. All adjusted models controlled for prenatal depression (BDI-II) or anxiety (STAI-S) scores, social support at two months, and concurrent negative emotions during infant feeding at two months.
Bolded results are significant at $p<0.05$.
[a] BDI-II: Beck Depression Inventory II scores range from 0 to 63, with higher scores indicating more depression symptoms
[b] Baseline psychopathology was determined via Structured Clinical Interview for DSM-IV in the third trimester of pregnancy. The "no diagnosis" group includes those with no history and those with a history of depression/anxiety, whereas the "prenatal diagnosis" group met criteria for an active disorder during pregnancy
[c] STAI-S: Spielberger State Trait Anxiety Inventory-State scores range from 20-80, with higher scores indicating more anxiety symptoms.

APPENDIX 3.1: ADDITIONAL AIM 2 ANALYSES

This section of the appendix provides additional information on Aim 2 model building and statistical analyses.

The DAG below conceptualizes the hypothesized relationships between positive emotions during infant feeding and breastfeeding outcomes based on the literature and subject matter expertise of the co-authors (Figure 3.1.1).

Figure 3.1.1: Directed Acyclic Graph (DAG) of the relationship between positive emotions during infant feeding and breastfeeding outcomes



We opted to conduct sensitivity analyses using the measure of maternal feelings toward breastfeeding in the first week postpartum instead of using selection weights to address potential immortal person time bias. Using selection weights would amplify the experience of the women who were unlikely to continue breastfeeding but continued nevertheless, based on their sharing characteristics with those no longer doing any breastfeeding at two months that predict the odds of breastfeeding. While we had several measures that predicted selection into the sample at two months, the women with those characteristics who remained in our sample likely had other characteristics that allowed them to continue breastfeeding despite all those early conditions that would make it unlikely. Instead of weighting my sample to make those exceptional people who

overcame early barriers count more (to represent themselves and the women who share certain characteristics but were not able to breastfeed), we opted to conduct a sensitivity analysis with a similar exposure measure from week one postpartum.

We used inverse probability of exposure weights to present unconfounded Kaplan-Meier curves by creating an analytic pseudopopulation where the confounders are balanced across high (>2.5-4) and low (0-2.5) levels of the positive emotions exposure. We confirmed that inverse probability weighting balanced our population across confounders by examining the distribution of covariates after weighting. To create inverse probability of exposure weights for the positive emotions during feeding at two months exposure, we used logistic regression to predict the likelihood of experiencing high (>2.5-4) versus low (0-2.5) positive emotions based on the distribution of confounders: baseline depression scores, social support, early breastfeeding problems, birth trauma, and negative emotions during infant feeding at two months. We chose this dichotomous classification for our weighted Kaplan-Meier curves, because it had the second most optimal model fit (AIC/BIC) with breastfeeding outcomes (after the continuous exposure measure). We weighted the population by the inverse probability of their actual exposure based on the distribution of their confounding covariates, and we stabilized the variance by multiplying each weight by the marginal probability of exposure (see Figures 3.2.1 and 3.2.2).

We used Cox proportional hazards models to determine hazards of any and exclusive breast milk feeding cessation, because these models can be used without having to specify a baseline hazard function (Allison, 2012). Despite a small loss in efficiency, these models are robust to various baseline hazard functions. We examined whether the proportional hazards assumption was appropriate for our data by examining martingale residuals (Allison, 2012) and found that none of the observed covariate patterns were more extreme than simulated patterns.

To address tied events occurring in our data, we assumed time to be continuous with a true but unknown ordering for tied event times, and approximated this underlying order using the Efron method. Because the number of ties was not a large proportion of the number of cases at risk, the Efron method was a good approximation (Allison, 2012).

We explored modification of the association between positive emotions and breastfeeding outcomes by women's baseline psychopathology: we tested modification by the presence or absence of clinical depression/anxiety during pregnancy via third trimester SCID and by risk status for postpartum depression/anxiety, where "high risk" was indexed by a SCID-confirmed history of depression/anxiety or an active depressive/anxiety disorder in pregnancy. Secondary analyses explored modification of the association between positive emotions during breastfeeding and time to any and exclusive breast milk feeding cessation by moderate/severe childhood trauma experience and by breast milk feeding status at two months. Linear regression models for experiences of positive emotions during breast milk feeding at two months and the total score and subscores of overall breastfeeding experience at 12 months were additionally probed for potential modification by whether or not the woman was any breast milk feeding at 12 months.

We conducted a sensitivity analysis testing the exclusion of women taking psychotropic medications, since their emotional experience and duration of infant feeding may be systematically different from women not taking these medications.

APPENDIX 3.2: ADDITIONAL AIM 2 RESULTS

Both positive emotions measures were left-skewed toward more positive emotions, while negative emotions during feeding at two months was right-skewed toward fewer negative emotions. Positive emotions during feeding at two months ranged from 0.4 to 4, with a median of 2.9 and interquartile range of 2.3 to 3.5. Positive feelings about breastfeeding in the first week ranged from 0 to 5, with a median of 4 and interquartile range of 2-5. Negative emotions during feeding at two months ranged from 0 to 2.6, with a median of 0.4 and an interquartile range of 0.2 to 0.8. While the MBFES outcome was slightly skewed toward higher scores, model residuals were normally distributed with few extreme outliers.

The weighted Kaplan-Meier curves for time to cessation of breast milk feeding were not significantly different by high versus low positive emotions (Figure 3.2.1). The weighted Kaplan-Meier curves for time to cessation of exclusive breast milk feeding were significantly different by high versus low positive emotions (Figure 3.2.2).

Figure 3.2.1: Weighted Kaplan-Meier curves and 95% confidence intervals for time to cessation of any breast milk feeding stratified by high (>2.5-4) versus low (0-2.5) positive emotions during breast milk feeding

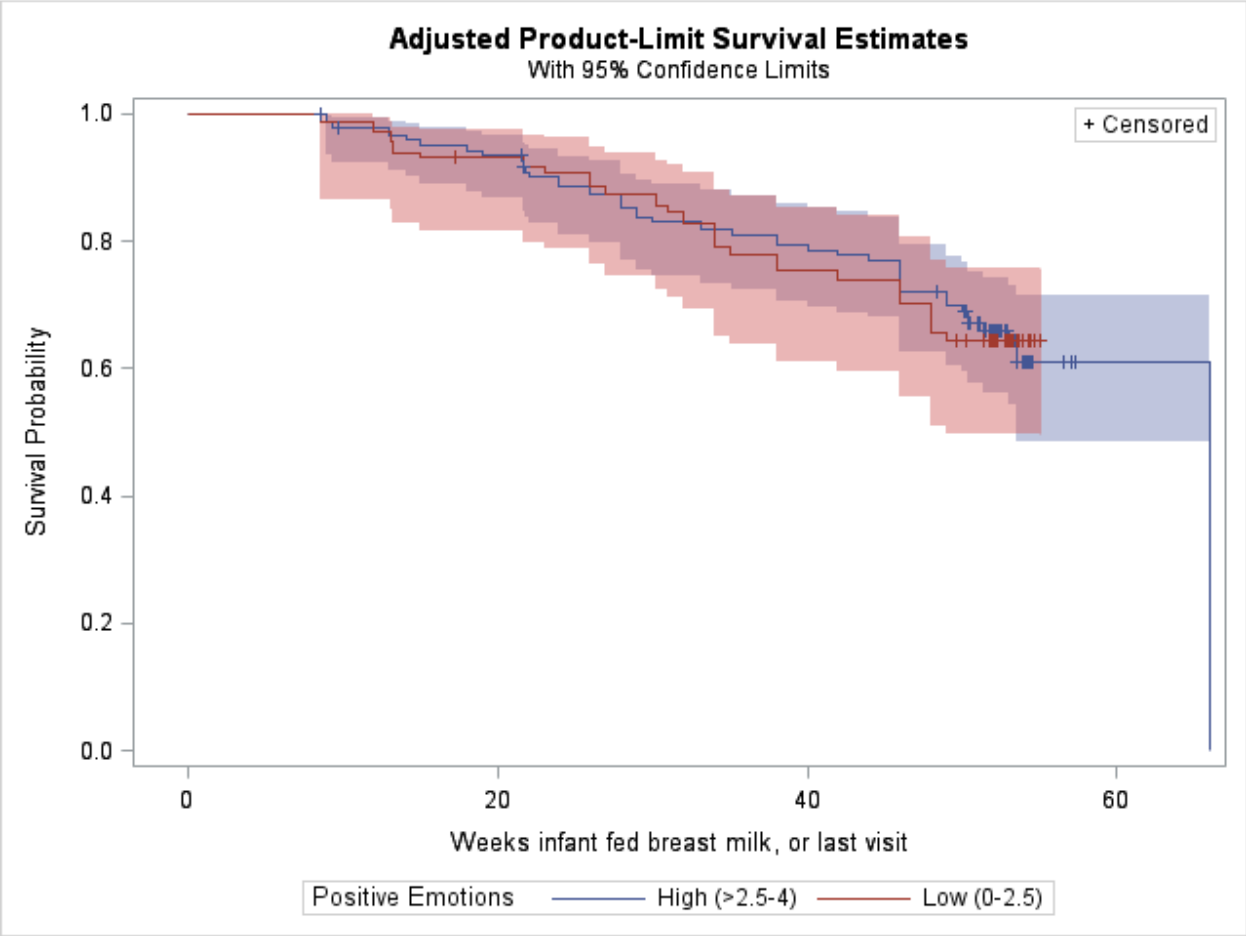
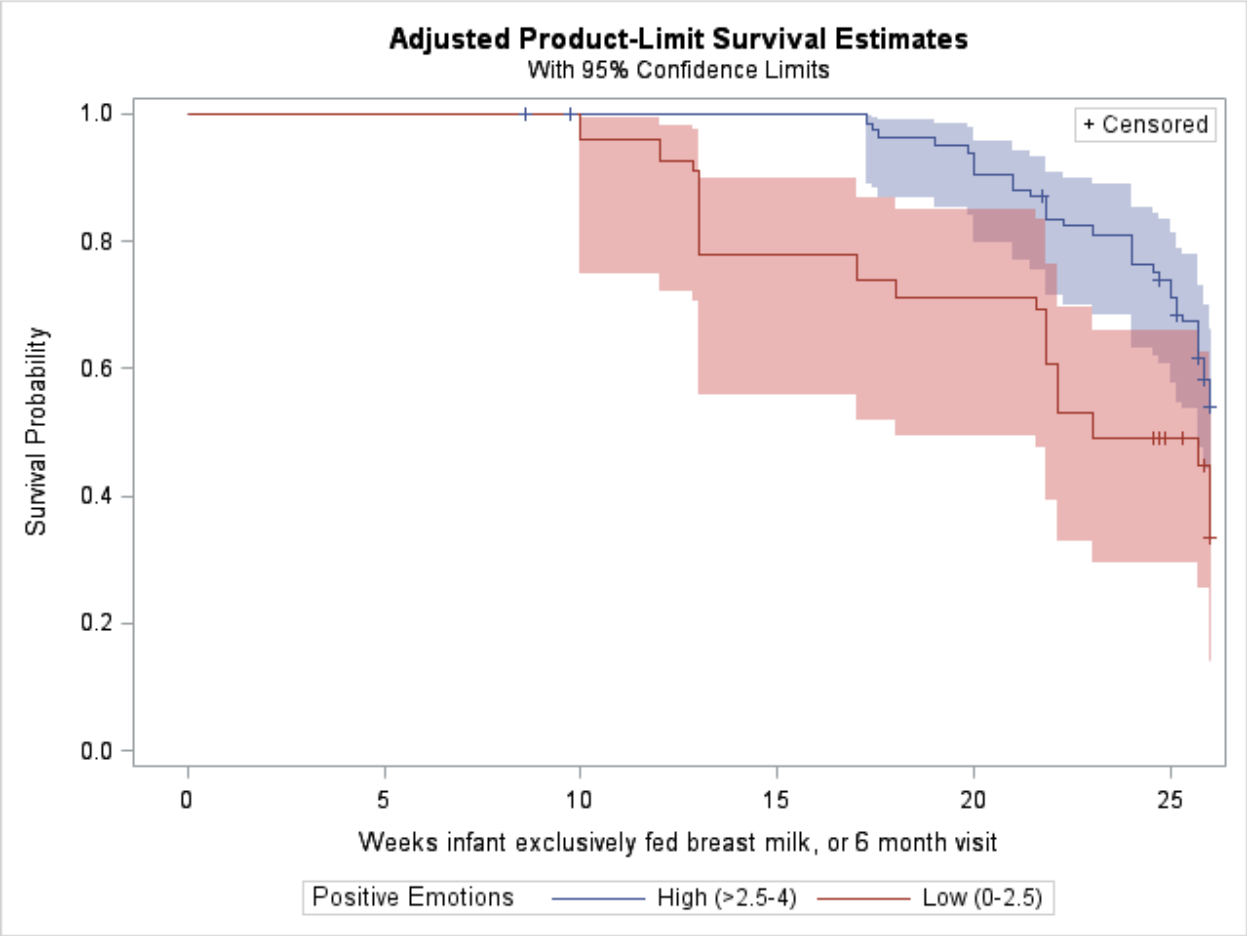


Figure 3.2.2: Weighted Kaplan-Meier curves and 95% confidence intervals for time to cessation of exclusive breast milk feeding



Baseline psychopathology did not significantly modify the association between positive emotions during infant feeding and breastfeeding outcomes (see Table 3.2.1).

Table 3.2.1: Estimates of association between a one-unit increase in positive emotions and time to any and exclusive breast milk feeding cessation and overall maternal evaluation of breastfeeding, adjusted for confounders: Modification by baseline psychopathology

	Positive emotions, month 2 postpartum				Positive emotions, week 1 postpartum			
	N	**Crude**	**Adjusted[c]**	***p* for inter-action**	**N**	**Crude**	**Adjusted[d]**	***p* for inter-action**
Any breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*			*HR (95% CI)*	*HR (95% CI)*	
Where any breast milk feeding at exposure	174	0.88 (0.64, 1.20)	0.94 (0.64, 1.31)		192	0.77 (0.65, 0.91)	0.87 (0.72, 1.06)	
By baseline risk for postpartum depression/anxiety				0.28				0.39
Low risk	62	0.65 (0.38, 1.13)	0.70 (0.40, 1.22)		70	0.81 (0.60, 1.08)	0.91 (0.67, 1.25)	
High risk, based on SCID diagnosis or history	112	0.99 (0.66, 1.47)	1.12 (0.72, 1.76)		122	**0.75 (0.61, 0.92)**	**0.72 (0.58, 0.89)**	
By baseline psychopathology				0.63				0.82
No active prenatal depression or anxiety	113	0.79 (0.56, 1.12)	0.88 (0.59, 1.29)		125	**0.78 (0.63, 0.95)**	0.86 (0.68, 1.09)	
Active prenatal depression or anxiety diagnosis	61	1.15 (0.57, 2.30)	1.13 (0.53, 2.45)		67	0.77 (0.59, 1.01)	0.76 (0.55, 1.04)	
Exclusive breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*			*HR (95% CI)*	*HR (95% CI)*	
Where exclusive breast milk feeding at exposure	114	0.74 (0.53, 1.03)	**0.65 (0.46, 0.92)**		185	**0.74 (0.66, 0.84)**	**0.77 (0.66, 0.89)**	
By baseline risk for postpartum depression/anxiety				0.61				0.81
Low risk	41	0.66 (0.29, 1.50)	**0.59 (0.23, 1.52)**		66	**0.78 (0.62, 0.99)**	0.78 (0.60, 1.01)	
High risk, based on SCID diagnosis or history	73	0.83 (0.57, 1.20)	0.76 (0.52, 1.12)		119	**0.74 (0.64, 0.85)**	**0.75 (0.63, 0.88)**	
By baseline psychopathology				0.93				0.75
No active prenatal depression or anxiety	75	0.70 (0.46, 1.06)	0.65 (0.41, 1.04)		121	**0.73 (0.63, 0.85)**	**0.74 (0.61, 0.88)**	
Active prenatal depression or anxiety diagnosis	39	0.88 (0.49, 1.56)	0.65 (0.32, 1.30)		64	**0.75 (0.61, 0.93)**	**0.77 (0.61, 0.97)**	
Overall experience of breastfeeding (MBFES)[b]		*Beta (95% CI)*	*Beta (95% CI)*			*Beta (95% CI)*	*Beta (95% CI)*	

Overall sample	186	**7.11 (4.29, 9.92)**	**5.96 (3.16, 8.76)**		186	**5.58 (4.01, 7.16)**	**4.74 (3.09, 6.35)**	
By baseline risk for postpartum depression/anxiety				0.38				0.76
Low risk	64	**8.91 (3.85, 13.96)**	**7.13 (1.86, 12.40)**		64	**5.00 (2.05, 7.94)**	**4.19 (1.37, 7.01)**	
High risk, based on SCID diagnosis or history	122	**6.00 (2.55, 9.44)**	**4.86 (1.46, 8.27)**		122	**5.60 (3.72, 7.48)**	**4.95 (2.99, 6.92)**	
By baseline psychopathology				0.41				0.16
No active prenatal depression or anxiety	120	**6.57 (3.17, 9.97)**	**5.53 (2.02, 9.04)**		120	**4.78 (2.73, 6.84)**	**4.28 (2.16, 6.40)**	
Active prenatal depression or anxiety diagnosis	66	**7.57 (2.54, 12.60)**	**5.45 (0.38, 10.52)**		66	**6.76 (4.42, 9.11)**	**6.32 (3.85, 8.80)**	

[a] Cox proportional hazards regression models were used to estimate hazard ratios (HR) for time to cessation of breast milk feeding and exclusive breast milk feeding.

[b] Linear regression models were used for continuous Maternal Breastfeeding Evaluation Scale total and subscore outcomes

[c] Models analyzing positive emotions at two months were adjusted for confounding by prenatal depression score, social support, professional lactation support in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding

[d] Models analyzing positive emotions at one week postpartum were adjusted for confounding by prenatal infant feeding intention score, social support, birth trauma, and professional lactation support in the hospital.

Bolded results are significant at $p<0.05$.

Secondary analyses showed no significant modification of positive emotions and any breastfeeding outcomes by breast milk feeding status at two months (Table 3.2.2) or by moderate/severe childhood trauma (Table 3.2.3). Breast milk feeding status at 12 months did not significantly modify the effect of positive emotions during feeding on the overall maternal evaluation of breastfeeding at 12 months (Table 3.2.3).

Table 3.2.2: Estimates of association between a one-unit increase in positive emotions during infant feeding at two months and time to any and exclusive breast milk feeding cessation, adjusted for confounders: Secondary analysis exploring modification by childhood trauma

	N	Crude	Adjusted[b]	*p* for interaction
Any breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*	
Where any breast milk feeding, 2 mo	174	0.88 (0.64, 1.30)	0.94 (0.64, 1.31)	
By childhood trauma experience				0.74
No trauma	122	0.91 (0.62, 1.32)	0.98 (0.65, 1.50)	
Trauma	46	0.81 (0.46, 1.45)	0.77 (0.38, 1.54)	
Exclusive breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*	
Overall	114	0.74 (0.53, 1.03)	**0.65 (0.46, 0.92)**	
By childhood trauma experience				0.22
No trauma	84	0.77 (0.53, 1.13)	0.70 (0.46, 1.08)	
Trauma	25	0.42 (0.16, 1.10)	0.44 (0.14, 1.36)	

[a] Cox proportional hazards regression models were used to estimate hazard ratios for time to cessation of breast milk feeding and exclusive breast milk feeding.
[b] Cox models were adjusted for confounding by prenatal depression score, social support, professional lactation support in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding
Bolded results are significant at $p<0.05$.

Table 3.2.3: Estimates of association between a one-unit increase in positive emotions and time to any breast milk feeding cessation and overall maternal evaluation of breastfeeding at 12 months, weighted for confounders and stratified by breast milk feeding status

		Positive emotions, month 2 postpartum		
	N	**Crude**	**Adjusted[c]**	***p* for interaction**
Any breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*	
Where any breast milk feeding at exposure	174	0.88 (0.64, 1.30)	0.94 (0.64, 1.31)	
By breast milk feeding status at two months				0.22
Exclusive	114	0.86 (0.48, 1.53)	0.76 (0.41, 1.40)	
Mixed feeding	60	1.30 (0.87, 1.95)	1.37 (0.89, 2.12)	
Overall experience of breastfeeding (MBFES)[b]		*Beta (95% CI)*	*Beta (95% CI)*	
Overall sample	186	**7.11 (4.29, 9.92)**	**5.96 (3.16, 8.76)**	
By breast milk feeding status at two months				0.68
Exclusive	110	**6.93 (4.11, 9.75)**	**5.82 (2.99, 8.66)**	0.68
Mixed feeding	58	**5.55 (0.74, 10.35)**	4.82 (-0.08, 9.71)	
No breast milk feeding	18	6.64 (-4.39, 17.67)	**10.56 (2.55, 18.58)**	
By breast milk feeding status at 12 months				0.29
No breast milk feeding	75	**7.82 (2.88, 12.76)**	**7.47 (2.68, 12.26)**	
Any breast milk feeding	110	**6.10 (3.51, 8.69)**	**5.85 (3.15, 8.56)**	

[a] Cox proportional hazards regression models were used to estimate hazard ratios (HR) for time to cessation of breast milk feeding and exclusive breast milk feeding.

[b] Linear regression models were used for continuous Maternal Breastfeeding Evaluation Scale total and subscore outcomes

[c] Models were adjusted for confounding by prenatal depression score, social support, professional lactation support in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding

Bolded results are significant at $p<0.05$.

Sensitivity Analyses Results

Our results generally remained robust to sensitivity analyses testing the exclusion of women taking psychotropic medications (see Table 3.2.2 below). The only difference from our main findings was no significant association between positive emotions and the lifestyle/maternal body image MBFES subscale after excluding women taking psychotropic medications.

Table 3.2.4: Estimates of association between a one-unit increase in positive emotions during infant feeding at two months and time to any and exclusive breast milk feeding cessation and overall maternal evaluation of breastfeeding at 12 months, excluding women taking psychotropic medications

	N	Crude	Adjusted[c]
Any breast milk feeding cessation[a]		*HR (95% CI)*	*HR (95% CI)*
Full sample	174	0.88 (0.64, 1.30)	0.94 (0.64, 1.31)
Excluding medicated	137	0.90 (0.63, 1.27)	0.98 (0.67, 1.44)
Exclusive breast milk feeding cessation[a]		*Hazard ratio (95% CI)*	*Hazard ratio (95% CI)*
Full sample	114	0.74 (0.53, 1.03)	**0.65 (0.46, 0.92)**
Excluding medicated	93	0.76 (0.52, 1.09)	**0.70 (0.47, 1.04)**
Maternal Breastfeeding Evaluation (MBFES)[b]		*Beta (95% CI)*	*Beta (95% CI)*
Full sample	186	**7.11 (4.29, 9.92)**	**5.96 (3.16, 8.76)**
Excluding medicated	144	**5.70 (2.61, 8.79)**	**4.87 (1.71, 8.04)**
By subscale, full sample			
Maternal Enjoyment/Role Attainment Subscale	186	**4.30 (2.68, 5.93)**	**3.88 (2.25, 5.51)**
Infant Satisfaction/Growth Subscale	186	**1.60 (0.40, 2.80)**	1.01 (-0.14, 2.17)
Lifestyle/Maternal Body Image Subscale	186	**2.15 (0.91, 3.39)**	**1.49 (0.28, 2.69)**
By subscale, excluding medicated			
Maternal Enjoyment/Role Attainment Subscale	144	**3.51 (1.73, 5.29)**	**3.27 (1.45, 5.09)**
Infant Satisfaction/Growth Subscale	144	1.13 (-0.18, 2.44)	0.57 (-0.74, 1.88)
Lifestyle/Maternal Body Image Subscale	144	**1.71 (0.30, 3.11)**	1.19 (-0.20, 2.58)

[a] Cox proportional hazards regression models were used to estimate hazard ratios (HR) for time to cessation of breast milk feeding and exclusive breast milk feeding.

[b] Linear regression models were used for continuous Maternal Breastfeeding Evaluation Scale total and subscore outcomes

[c] Models were adjusted for confounding by prenatal depression score, social support, professional lactation support in the hospital, birth trauma, number of breastfeeding problems in the first two weeks, and negative emotions during infant feeding

Bolded results are significant at $p<0.05$.

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