M(other) Nurture:
Exploring the Influence of Maternal Care on the Development of Infant Emotion Processing, Regulation, and the Emotional Brain

by

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DEDICATION

To my family, who are my safe haven

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ABSTRACT

The overarching goal of this dissertation was to examine the link between infant emotional development and the caregiving environment. Study 1 focused on the Face-to-Face Still-Face Paradigm (FFSF), in which in vivo interactions between infants and their caregivers are observed. Person-centered analyses were used in order to identify individual differences in FFSF responding based on positive and negative affect at 3 and 7 months. Four classes were found at both timepoints: Social-Positive Oriented, Classic Still-Face, Self-Comfort Oriented, and Distressed Inconsolable. Although number of profiles and their descriptions remained stable from 3-7 months, the infants in each class changed over time. Maternal engagement differed between the Social-Positive Oriented class and Distressed-Inconsolable class at 7 months. We found a significant relationship between the groups we identified at 7 months and attachment quality at 14 months. Study 2 utilized Functional Near Infrared Spectroscopy (fNIRS) to explore the influence of infant temperament and maternal stress on infant medial prefrontal cortex (mPFC) activation in response to angry, happy, and sad emotion faces. A dimension of infant temperament, negative emotionality, predicted significant brain activation across all emotion face conditions. Mother-infant dysfunctional interaction was associated with an increased brain activation response to happy faces. This study provides additional evidence that both maternal caregiving and infant temperament influence the way an infant's brain processes emotions, demonstrating the importance of early dyadic interaction and its connection with the novelty hypothesis.

CHAPTER 1: General Introduction

In 1952, pediatrician Donald Winnicott stated, "There is no such thing as a baby ... if you set out to describe a baby, you will find you are describing a baby and someone". With this statement, Winnicott underscored the concept that infant development is dependent on the quality of caregiving received. Current research in early childhood has supported this emphasis on the parent-infant relationship, identifying sensitive caregiving during the first year of life as essential for long-term physical and psychological outcomes (Schore, 2015; Fonagy & Higgitt, 2000). More recently, studies investigating infant brain development have established that specific brain systems responsible for emotion regulation and self-organization are formed directly by responsive parental care (Hart & Rubia, 2012). Although the importance of the family context has been demonstrated most strikingly in the case of Romanian Orphans, whose severe deprivation led to a host of long term, negative, social emotional consequences (Zeanah, Smyke, Koga, & Carlson, 2005; Kaler & Freeman, 1994), we are all marked by our early experiences (Schore, 2001). Thus, rather than being thought of as a "natural" progression, brain development should be viewed as a reflection of a relational experience (Gunnar, 1998; Schore, 2005).

The Development of Emotion Regulation

Operating from a relational and transactional framework, the development of early emotion regulation is best viewed as shifting from mutual regulation between infant and caregiver with the infant's dependence on the caregiver for emotion regulation, to self-regulation, and the infant's ability to employ these strategies on their own (Sameroff, 2009). This dissertation seeks to investigate and identify the neurological, affective, and behavioral networks related to the development of emotion regulation in the first year of infancy, as developmental outcomes are largely dependent on the successful employment of healthy self-regulation strategies, or the ability to organize and manage emotions (Gross, 2002). Because later emotional development builds on the regulation skills acquired during infancy, understanding these mechanisms in the formation of early emotion regulation is an important step in uncovering developmental processes.

Throughout infancy, caregivers aid in managing the emotions of their children by soothing distress through different means such as cuddling and rocking. At this point in time, infants are unable to regulate their own emotions, and therefore, rely on these caregiver interventions to manage their emotions and to help them learn successful strategies for future regulation (Fox & Calkins, 2003). During this time, the primary caregiver is also acting as the infant's prefrontal cortex, given the prefrontal cortex is the "executive center" for the development of self-regulation. Infants are unable to regulate their emotions without external support because the brain structures they need to do so are still developing. When caregivers do not aid in the regulation of stressful experiences in infancy, this can lead to emotion dysregulation, which is a core feature in many psychological disorders (Nelson & Bosquet, 2000).

Infant Emotional Brain Development

Brain development is not the direct result of straightforward, automatic growth based on genetics, but highly susceptible to environmental influence. Regions of the brain most susceptible to environmental influence, such as the prefrontal cortex, are those whose major development happens outside the womb (Schore, 1994). Because the majority of brain development, including complex cortical structures, occurs during infancy, parents essentially act as regulators of brain maturation (Haracz, 1985). Studies investigating the development of brain growth patterns of maltreated children have demonstrated that healthy brain development—particularly the development of the prefrontal cortex (PFC)—is dependent upon the quality of the caregiving received (Schore, 1994).

The PFC is the anterior portion of the frontal lobe, and responsible for the most complex brain processes. The PFC sends and receives information from almost all other structures in the brain and organizes thoughts and behaviors in an attempt to accomplish internal goals (Miller & Cohen, 2001). In order to regulate emotions, the PFC exerts inhibitory control on the amygdala through the medial prefrontal cortex (mPFC), an area of the cortex directly connected to the amygdala (Urry et al., 2006). The amygdala is the major brain structure involved in emotional processing and the learning of emotional responses. The amygdala pairs environmental input with emotional responses, such as fear in response to loud noises (Cardinal, Parkinson, Hall, & Everitt, 2002). This is how individuals learn to categorize stimuli as inducing various emotions, both negative and positive (Tottenham, 2010).

Empirical Studies that lay the Groundwork for this Research

In adulthood, there is an inverse connection between the amygdala and the mPFC, meaning that when the mPFC is highly activated, the amygdala is inhibited and less active. During childhood (until age 10), however, imaging studies have found a positive connection between these two structures (Gee et al., 2014). This immature connectivity pattern is one of the reasons that it is so difficult for children to self-regulate, because the neural mechanisms responsible for emotion regulation have not fully developed (Gee, et al., 2013).

Previous studies with rats have demonstrated that mother rats provide regulatory scaffolding when their pups are young and lack the ability to regulate the activity of key prefrontal regions (Moriceau & Sullivan, 2006). Gee et al. (2014) explored this concept between human infants and their mothers in an attempt to identify the underlying neural mechanisms of the co-regulation process, focusing on the connectivity between the amygdala and the medial prefrontal cortex (mPFC). Their findings demonstrated that maternal presence (both visual and in person) acts as an external regulator on amygdala-prefrontal cortex circuitry during childhood. Additionally, children with secure attachments showed greater maternal influence on amygdala-prefrontal circuitry than those who displayed more insecure attachments (Gee et al., 2014). In essence, the strength of the mother-child bond was directly tied to emotion regulation through amygdala-medial prefrontal cortex functioning. Although we hypothesize that this neural process is similar for human infants, there is a lack of empirical evidence.

The Present Dissertation

The main goal of this dissertation was to examine the development of the infant emotional brain and how early parent-infant interactions contribute to the neural, affective and behavioral underpinnings of early social-emotional development and the development of early emotion regulation. This dissertation is especially innovative in pairing novel methodologies with standard developmental paradigms. In study one, for example, person-centered analyses are used to analyze infant affective and behavioral responses to the Face-to-Face Still-Face, and study two utilizes fNIRS (functional near infrared spectroscopy), a relatively new neuroimaging technology that is suited to studying infant brain development, in examining an emotion processing task. These studies build directly on well-established developmental methods for assessing infant social and emotional responsivity and deepening our understanding of these constructs. This dissertation seeks to supplement the literature in two areas:

1. Identify how infant affect and behavior become organized through the use of the mother as a regulation object and stabilize by the end of the first year.
2. Identifying the neural mechanisms utilized in emotion processing, and how these structures work in tandem with the quality of the mother-infant relationship ---both affective and behavioral—to generate individual differences in brain responses to emotions.

The first study of this dissertation will focus on the shift from mutual to self-regulation, and the second study will focus on the neuroscience of infant emotion processing. Study one utilizes secondary, longitudinal data with a (relatively) large sample, whereas study two focuses on primary collection of neuroimaging data focusing on temperament and maternal reports of parenting stress, with a small sample of infants (*N* = 16). Taken together, these two studies complement one another in that study one takes a more “macro” approach to the development of emotion regulation in examining trajectories of development over the course of eleven months, whereas study two examines the minutiae of brain activation over the course of nine minutes. Ultimately, both reveal important aspects of infant emotional development.

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CHAPTER 2: (Study 1) At face value: Developmental trajectories of emotion regulation in the Face-to-Face Still-Face paradigm in the first year of infancy

The Face-to-Face Still-Face Paradigm (FFSF) has been used since 1978 to study infant communication patterns, caregiver sensitivity and infant emotion regulation abilities (Tronick et al., 1978). This paradigm consists of three episodes each lasting two minutes and has been used with infants ranging in age from newborn to 9 months (Weinberg & Tronick, 1994). In the first episode, mothers engage in free face-to-face play with their infant with no instruction. During the second "still-face" episode, mothers are told to assume a neutral face and remain unresponsive to their infant, no matter how he or she reacts. The final reunion episode consists of the mother re-engaging with the infant (Weinberg & Tronick, 1996).

Regulation strategies utilized by infants during the FFSF are often hypothesized to be the developmental precursors to the formation of attachment relationships at the end of the first year of infancy (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). There is mixed evidence, however, supporting this premise (Cohn, Campbell, & Ross, 1991; Mesman et al., 1999). For example, Jamieson (2001) found a significant association between 4-month-old infants' levels of negative affect and length of gaze at mother during the FFSF and attachment avoidance at 12 months, whereas another study (Kogan & Carter, 1996) found no association between 4-month-old infants' responses in the FFSF and attachment security at 12 months. In their meta-analysis, Mesman et al., (1999) highlighted these inconsistent findings across studies utilizing the FFSF, which may be due to the manner in which infant affect and regulatory behaviors observed during the FFSF are coded and then analyzed to predict subsequent attachment quality. Most studies use variable-centered approaches in which infant affect and regulatory strategies are considered as independent predictors of the security of the infant-mother attachment relationship (Mesman et al., 1999). Because not all infants react similarly during the FFSF (Mesman et al., 1999), more recent efforts have used person-centered analytic approaches to capture behavioral and affective profiles during the FFSF that are shared by groups of individuals. The purpose of the current study was to add to this literature by using person-centered analyses (Latent Profile Analysis: LPA) to uncover individual differences in positive and negative affective trajectories during the FFSF at two developmental periods (3 and 7 months) in the first year of infancy, and then relate these profiles to the security of the infant-mother attachment relationship at 14 months.

Individual Differences in Infant Responses to the Face-to-Face Still-Face

The FFSF is one of the primary means of assessing the development of infant emotion regulation. The task consists of three episodes, each lasting two to three minutes, involving the infant and mother seated face to face across from one another (see Weinberg & Tronick, 1996). During the first episode, the *free play* episode, mothers are instructed to play with their infant as they normally would. During the second episode, known as the "*still-face*", mothers are instructed to assume a neutral expression and not to respond to the infant. In the final *reunion* episode, mothers reengage with infants in playful interaction. The "classic still-face effect" is one in which there is a decrease in positive affect and an increase in negative affect during the still-face episode compared to the initial free play episode, with partial recovery during the reunion episode (Mesman et al, 2009; Tronick et al., 1978). However, not all infants exhibit a decrease in positive affect and increase in negative affect in the still-face episode (Barbosa, Beeghly, Moreira, Tronick, & Fuertes, 2018; Motirosso et al., 2015; Papoušek, 2007) suggesting that there may very well be different profiles describing changes in infant positive and negative affect over the three episodes.

To date, few studies have considered a person-centered approach to reveal individual differences in trajectory profiles of negative and positive affect across the episodes of the FFSF. For the few studies that have, multiple groups (or classes) have been found, underscoring individual differences across infants (Barbosa et al., 2018; Motirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018). For instance, relying on a coding system that distributed infants into similar groups based on individual differences in affect and behavior during the FFSF, Barbosa et al. (2018) identified three groups at 3 and 9 months: (1) a *social-positive oriented* group that demonstrated high positive affect across the FFSF, with a slight decrease in positive affect (but no increase in negative affect) during the still-face episode that then rebounded during the reunion: (2) a *distressed-inconsolable* group that had high negative affect across all episodes of the paradigm, particularly during the still-face episode, and were not able to calm down during the reunion episode; and (3) a *self-comfort-oriented* group that exhibited avoidant behaviors, such as gaze aversion, with their mothers during the free play and reunion episodes and attempted to comfort themselves rather than relying on their mothers for regulatory purposes.

In the remaining set of person-centered studies, infants often varied with respect to the age at which the FFSF was conducted (from 2 to 9 months), as well as the number of classes found (from three to five). Yet, each study was remarkably similar in identifying different classes, in which infants within each class were remarkably similar in the trajectory profiles of expressed negative and positive infant affect in the FFSF. Consistent with Barbosa et al (2018) described earlier, three groups appear to emerge consistently from these person-centered analyses. The large majority of infants in these person-centered studies did not demonstrate the classic still-face effect, but instead, the majority of infants expressed stable positive affect across the free play, still-face, and reunion episodes, with minimal decline or increase in negative affect (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007). A substantial number of infants were characterized by high levels of negative affect across the paradigm, with an increase during the still-face episode that did not fully decline during the reunion episode (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018), and still others, exhibited low levels of positive and negative affect across all three episodes of the FFSF and relied on themselves for comfort and self-soothing (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007). In order to add to this literature, the first aim of this study was to use person-centered analyses to identify individual differences in infant affect during the FFSF.

A Developmental Perspective on the FFSF

Even though infant emotion regulation is theorized to change significantly over the first year, with a greater reliance on external supports provided by the caregiver early in life and a greater ability to use more self-focused regulation strategies over time (Sameroff, 2009; Sroufe, 1996), most studies have only conducted the FFSF at one point in time during the first year of infancy, and are not in a position to see if infants perform similarly in the FFSF at different points in the first year. One would expect older infants to be better regulated than younger infants and perhaps be less distressed by the still-face. If so, then patterns of infant affect may be different from early to later in the first year. Only one previous study has utilized person-centered analyses to examine infant trajectories of affective and behavioral profiles using the FFSF at 3 and 9 months (Barbosa et al., 2018), finding the same three classes at each timepoint: *social-positive oriented* (53%), *distressed-inconsolable* (33.9%), *and self-comfort oriented*

(12.5%). Further, membership in these classifications was stable across the two timepoints with most infants classified the same at each time. Therefore, the second aim of this study was to assess stability of class membership across 3 and 7 months.

Longitudinal Prediction of Attachment Security using FFSF

Most of the research looking at the links between infant responses to FFSF and attachment security at the end of the first year have relied on variable-centered approaches. As one example, a longitudinal study by Braungart-Rieker et al (2014) conducted the FFSF at 3, 5, and 7 months, and found that while infants who were later classified as insecure-ambivalent in the strange situation procedure at 12 months demonstrated a decrease in positive affect from the free play to the still-face episode (a continuous downward trajectory) and an increase in positive affect from the still-face to reunion episode—although less of an increase than the infants classified as secure. Further, insecure-ambivalent infants also demonstrated greater levels of self-comforting than the secure group across all episodes of the paradigm. Significant prediction was found at 3 and 5 months, but not 7 months. Other studies have successfully predicted attachment security utilizing the FFSF at 3 months (Fuertes, Lopes dos Santos, Beeghly, & Tronick, 2006), 4 months (Braungart-Rieker, et al., 2001; Braungart-Rieker et al., 1999), and 6 months (Cohn et al., 1999; Tronick et al., 1982).

Because few studies have taken a person-centered approach to the FFSF, only Qu & Leerkes (2018) have explored the association between trajectory profiles found at 6 months in the FFSF and the security of the infant-mother attachment relationship at 12 months and found associations between their profiles and attachment security. Specifically, their *highly distressed but regulating* profile displayed “better” attachment outcomes (i.e., lower scores on the negative attachment variables) and were able to utilize their caregivers to regulate their emotions during the Strange Situation Paradigm (SSP), their*over-regulated* group demonstrated the highest level of attachment avoidance, which means that they avoided their caregivers and did not rely on them for soothing during the SSP, the *resilient-to-distress*class was characterized by secure attachment outcomes, relying on their caregivers to help them regulate successfully, while their *under-regulated*profile demonstrated the highest level of attachment resistance, actively resisting their caregiver's attempts to aid in their regulation. This suggests that trajectories of regulation in the FFSF were related meaningfully to security of the infant-mother attachment relationship in the study. Thus, this provides some evidence that person-centered trajectories are a valid way to analyze FFSF data if interested in the associations with attachment.

Although there is some evidence that the FFSF and the SSP are linked, there is little cohesiveness across studies linking the FFSF and attachment security, given the different time points examined, the diverse coding systems used to assess infant behaviors and affect, the dissimilar analysis strategies conducted, and the different ways of analyzing attachment outcomes (classifications, composites). Thus, relations between the FFSF and attachment remains uncertain, and define our third aim of examining the link between groups identified during this study and attachment quality. This study adds to the literature by providing more examination of the relationship between the FFSF and attachment outcomes.

Maternal Behavior and Infant Responses in FFSF

Caregivers play a key role in the development of self-regulation and attachment security as infants shift from mutual regulation to self-regulation across the first year of life and "learn" how to regulate their emotions during interactions with a sensitive caregiver (Sameroff, 2009). A number of studies have found relations with maternal sensitivity and infant responses in the FFSF. For example, Kogan and Carter (1996) conducted the FFSF when infants were 4 months old and found that high levels of maternal sensitivity during the free play episode predicted infants who were able to use their mother's to regulate and calm down during the reunion episode, whereas less sensitive mothering during the free play episode predicted avoidant and/or resistant behaviors during the reunion episode of the FFSF.

Montirosso et al. (2015) recently examined the *reunion episode* specifically and found that their *socially engaged group*, the group with the highest levels of positive engagement and low percentage of negative engagement during the reunion episode, had the highest levels of matching and repair between mothers and infants throughout the *free play* and *reunion* episodes of the FFSF, indicating that these mothers were the most sensitive and attuned to their infants. The *disengaged group*, with the lowest percentage of both positive and negative engagement, had moderate levels of dyadic behavioral and affect matching between mothers and infants during the reunion episode. The *negatively engaged group*, with a complete absence of positive engagement, experienced the greatest level of maternal social monitoring and negative affect across the FFSF. Thus, this study provides evidence that maternal caregiving behaviors are associated with infant behaviors during the reunion episode of the FFSF.

Further support for relations between infant and maternal behavior in the FFSF can be found in a study of sixty 2- to 6-month-old infants by Papoušek (2007) who identified five distinct classes of infants' responses in the FFSF, and reported further that maternal behaviors (e.g., highly attuned maternal behavior versus intrusive and overstimulating maternal behavior) differed across classes. Pattern A, similar to the *classic-still face effect* class described earlier, was characterized by infant positive affect during the free play episode, distress during the still-face episode, and avoidance at the beginning of the reunion with an increase in positive affect later in the reunion. Mothers of these infants demonstrated high attunement during the FFSF free play episode. Pattern B displayed positive reciprocity, low visual contact, and a high interest in objects during the free play episode, and smiling, return of interest to objects, and a lack of distress during the still-face episode. Mothers of these infants demonstrated positive contingent responsiveness during the free play episode. Pattern C, similar to the *self-comfort oriented* group (Barbosa et al., 2014), displayed low rates of visual contact and smiling, some signs of distress and self-comforting behaviors across the FFSF. Mothers of these infants lacked positive facial expressions and contingent responsiveness during the FFSF. Pattern D was characterized by hyperarousal, negative affect and a lack of regulatory behaviors in all episodes of the FFSF, similar to *the distressed-inconsolable* group, and had mothers who were overstimulating when interacting with their infants during the free play and reunion episodes. Finally, pattern E displayed negative affect combined with self-comforting behaviors during the free play episode, an increase in smiling and positive affect during the still-face and unresponsiveness during the reunion. These mothers demonstrated intrusive and over-stimulating behaviors during the free play and reunion episodes. These findings indicate that that there is an association between maternal behavior and infant responses during the FFSF. Our final aim , therefore, was to examine whether our groups would differ with respect to maternal behaviors.

The Current Study

The current study extended prior research on infant emotion regulation in the FFSF and the development of infant-mother attachment relationships, and had four aims: (1) to use person-centered analyses to explore group-based trajectories of infant positive and negative affect across the FFSF using data collected at both 3 and 7 months of age and (2) to determine if they were similar or different across time; (3) to determine whether the resulting latent trajectory profiles of infant positive and negative affect also differed with respect to infant behavioral regulation and maternal behaviors observed during the FFSF; and finally, (4) to relate these trajectory profiles in the first year with the security of infant-mother attachment at 14 months of age.

Based on the previous person-centered FFSF studies (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018), we expected to identify at least four latent profiles using latent profile analysis (LPA): (1) one group that demonstrated high positive affect across the paradigm with only a slight increase negative affect during the still-face episode, (2) a group that reflected the "classic still-face effect" characterized by a decrease in positive affect and an increase in negative affect during the still-face episode compared to the initial free play episode, with partial recovery during the reunion episode, (3) a group whose distress increased throughout the episodes and was unable to use their caregiver to regulate and, (4) a group who exhibited neutral affect throughout the paradigm and relied on self-comforting behaviors rather than their mother. Because we know that maternal behavior scaffolds the development of emotion regulation early in life (Sameroff, 2009), we hypothesized that the less sensitive the mothers were across the free play and reunion episodes, the more difficulty the infant would have in utilizing effective regulation strategies, and be unable to use their mothers to regulate during the reunion episode (Tronick, 1978). We also hypothesized that, because emotion regulation abilities theoretically become more organized over time (Schore, 1994; Kopp, 1989), the groups identified at 3 and 7 months may not be stable. Lastly, we wanted to explore whether these groups would be associated with attachment quality at 14 months, in light of the inconsistent findings in the literature that the FFSF predicts attachment quality (Mesman et al., 2009).

Methods

Participants

Participants included 154 mother-infant dyads involved in a longitudinal study investigating the effects of maternal perinatal mental health across the first year of infancy. Pregnant women were recruited through obstetric offices affiliated with a large Midwestern university into high-risk (a history of at least one episode of depression) and low-risk (no history of depressive episode) groups for postpartum depression. Women were eligible to participate if they were over 20 years old with no chronic medical conditions, substance dependence or abuse, or diagnosis of eating disorders or bipolar disorder. Potential participants were administered the Structured Clinical Interview for DSM-IV (SCID-IV) by clinicians at 28-weeks prepartum and were eligible for the study if they were not currently depressed but had a history of depression, making them at-risk for future depressive episodes. They were then categorized into low risk ($N = 25$), and high risk groups ($N = 58$). All infants had to be born full-term (> 37 weeks) and have a birth weight greater than 2,500 grams.

Mothers ranged in age from 21 to 43 years, $M = 30.49$, $SD = 4.96$. The majority were married (83.8%). Seventy-five percent of the sample identified as white, 6.5% as Asian or Pacific Islander, 9.7% as African American, 4.5% as Hispanic, and 3.9% as other. The majority of the mothers had completed college (26.8%) or a graduate degree (35.3%). Forty-nine percent of the mothers were working full-time whereas 19.5% were working part-time. Over 50% had a household income of greater than $70,000.

Procedures

This longitudinal study included multiple time points throughout pregnancy and the postpartum period (see Marcus et al., 2011; Thomason, et al. 2014), but we focus on the three postpartum time points (3 months, 7 months, and 14 months) here as they are the source of information for the current report. The goal of the larger, comprehensive study was to examine the development of infant behavioral and physiological regulation across the FFSF in the context of the maternal psychosocial environment. A home visit was conducted at both 3 and 7 months and consisted of three interactive paradigms: (1) a five minute free play in which the mother was instructed to play with her infant as she normally would; (2) the FFSF with three two minute episodes (play, still face, reunion), and (3) a three minute teaching task that consisted of the mother attempting to teach the infant to swipe or bat at a ring toy. When infants were 14 months of age, mothers and infants visited the university laboratory where the Strange Situation Procedure (SSP) was conducted.

The current study utilized observational data of the Face-to-Face Still-Face Paradigm (FFSF) at 3 and 7 months, and SSP at 14 months. Due to attrition, 82 mother-infant pairs remained in the study at 14 months. These women differed significantly from the 154 recruited for the study in that they were significantly older, $t(82) = 2.06$, $p = .04$, had more education, $x^2(4, N = 82) = 21.71$, $p < .001$, had higher household incomes, $x^2(20, N = 82) =$, $p < .05$, and were more likely to be married, $x^2(4, N = 82) = 0.54$, $p < .01$. Participants also differed in the composition of racial group representation at 14 months, $x^2(4, N = 82) = 13.02$, $p < .05$, with an increase in the percentage of white participants and a decrease in all other racial groups. See Table 1 for demographic and background characteristics.

Measures

Face-to-Face Still-Face Paradigm. The FFSF is a standard procedure used to evaluate the infant's ability to regulate their emotions (Tronick, Als, Adamson, Wise, & Brazelton, 1978). The protocol used for the FFSF was adapted from the Michigan Family Study, a longitudinal study of infant regulation and development (McDonough, 1994). In their study, the FFSF was conducted at the library while data was collected for the present study during the home visits. During this paradigm, the mother sits in a chair facing her infant and is instructed to play with the infant without using toys for two minutes (free play), then to hold a neutral, unwavering face for two minutes (still-face), then to play with the infant again for two minutes (reunion). There are 5 second pauses between these sessions and the paradigm was discontinued if infants became increasingly distressed for more than 30 seconds (Rosenblum, McDonough, Muzik, Miller, & Sameroff, 2002).

Coding of infant and maternal behaviors in the FFSF. To examine infant and maternal behaviors during the FFSF, a coding system adapted by Rosenblum et al. (2002) from Kogan and Carter (1996) was used to provide global ratings of infant and maternal behaviors during the three episodes of the FFSF, using 3-point rating scales from 0 (none) to 3 (predominant) by three trained coders. Reliability was calculated on a randomly chosen 25% of the sample using Cohen's Kappa (Cohen, 1968) and are reported in parentheses.

For infants, each episode of the FFSF (free play, still-face, and reunion) was rated on eight behaviors and included: (a) *positive affect* (κ = .766) - pleasant interaction, including smiling and laughing; (b) *negative affect* (κ = .938) - negative interaction, including crying, whining, and fussing; (c) *arousal* (κ = .827) – increased protest in response to maternal bids; (d) *avoidance* (κ = .868) - ignores mother's attempts to engage; (e) *resistance* (κ = .827) - seems angry or pulls away from mother; (f) *seek maintain* (κ = .888) - attentive and responsive to mother; (g) *distress regulation* (κ = .937) - infant's pattern of regulating distress; and (h) *self/object* (κ = .777) (coded during the still-face episode only) - infant involvement with self/objects that are not the mother

For mothers, ten maternal behaviors were coded during the free-play and reunion episodes, and included (a) *engagement (κ* = .74*)* - successful positive engagement in interaction with the infant; (c) *sensitivity during distress (κ* = .93*)* - appropriate and sensitive response to infant distress; (d) *sensitivity during non*-distress *(κ* = .604*)* - appropriate and sensitive interaction with the infant generally; (e) *intrusiveness (κ* = .813*)* - rough handling of the infant; (f) *positive affect (κ* = .749*)* - smiling, soothing, and positive vocalizations; (g) *tension or anxiety (κ = 68.)* - nervous about her interactions with the baby). Sensitivity to distress and sensitivity to non-distress were averaged to create a more robust composite of maternal sensitivity.

Strange Situation Procedure. The SSP (Ainsworth, Blehar, Waters, & Wall, 1978) is a 21-minute procedure that consists of seven 3-minute episodes, in addition to a brief 1-minute introduction, and a series of separations and reunions that is intended to assess the security of the parent-infant attachment relationship. The reunions (episodes 5 and 8) were coded using four 7-point rating scales to assess (a) *proximity seeking* - effort and initiative in seeking physical contact from the mother, (b) *contact maintenance* - effort to maintain physical contact with the mother, (c) *resistance* - resistance to interaction and physical contact with mother, and (d) *avoidance* - efforts to avoid interaction or physical contact with mother, which are used to classify infants into three attachment groups: insecure-avoidant (A), secure (B), and insecure-ambivalent (C). Interrater agreement was 89.36% and disagreements were resolved through discussion. In addition, each SSP was rated using the D-rating system (Main & Solomon, 1990) to classify infants as disorganized (D) or not. For purposes of analyses, infants were classified into A, B, C, and D classifications.

Data Analysis Plan

To investigate the development of different emotion regulation trajectories across the 3- and 7-month FFSF, we used Latent Profile Analysis (LPA), a non-parametric, exploratory, person-centered analysis, to identify groups of infants expressing similar affective profiles (Gibson, 1959; Vermunt & Magidson, 2002). LPA allowed us to determine if similar trajectory patterns reported in earlier FFSF studies using person-centered approaches (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007) could be replicated in the current study at both 3 and 7 months. Previous patterns reported included, (1) the *classic still-face effect* or a decrease in positive affect and increase in negative affect from the free play to still-face episode, and partial recovery during the reunion episode (Qu and Leerkes, 2018; Mesman et al., 2009; Tronick et al., 1978); (2) a s*ocial-positive oriented* group that presented with high positive affect across all three FFSF episodes (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007), (3) a *distressed-inconsolable group* in which infants were distressed across all three episodes (Barbosa et al., 2018; Qu & Leerkes, 2018; Montirosso et al., 2015; Papoušek, 2007), and (4) a *self-comfort oriented group* in which infants demonstrated low levels of both positive and negative affect across the paradigm and relied on themselves for comfort (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007).

Latent Profile Analysis is unique in that classes can be created based on multiple indicator variables such that the covariance of these variables within a certain class are restricted (Lazarfeld & Henry, 1968). Therefore, classes can be created based on the relations between multiple variables with one another. This allowed us to consider the variables we thought were most fundamental in the FFSF and represented widely in the FFSF literature: positive and negative affect. We hypothesized that there would also be individual differences in infants' positive and negative affective trajectories across the FFSF, because although many different coding systems have been used with the paradigm, positive and negative affect are consistently coded across studies and are considered important markers of infant responses to stress (Mesman et al., 2009). LPA analysis allowed a multivariate approach in which infant positive and negative affect were simultaneously modeled as parallel processes occurring simultaneously across the three episodes of the FFSF rather than analyzing negative and positive affect as independent trajectories.

Once the different affective trajectories were revealed, we then conducted repeated measures ANOVAs to examine mean differences in infant behaviors coded during the FFSF across profile classes to provide further insights into class differences in infant regulation and help provide labels for the different infant profiles of emotion regulation. A similar analysis was conducted to address our second aim to examine whether infant affective profiles differed with respect to maternal behavior exhibited across the episodes of the FFSF. Finally, chi-squared analyses were conducted to determine if the different classes of emotion regulation trajectories were associated with the SSP attachment classifications at 14 months.

Results

Profile solutions were evaluated with LPA at both 3 and 7 months for 2, 3, 4 and 5-class models. Based on fit indices, results indicated that at 3 months, the four-profile solution was the best fit (AIC = 1411.7, BIC =1498.0, LMRT-LRT *p*-value = .06, Entropy = .98). Although the five-profile model (AIC = 1354.9, BIC = 1459.5, LMRT-LRT *p*-value = 0.7, Entropy = 0.97) provided the lowest AIC and BIC values and a stronger level of entropy, there were only two infants in the fifth class which led to our conclusion of the four-profile solution. . At 7 months, results also suggested a four-profile choice (AIC = 1130.13, BIC = 1213.0, LMRT-LRT *p*-value

= 0.8, Entropy = 0.95) over the three-profile (AIC = 1208.21, BIC = 1273.5, LMRT-LRT *p*-value = 0.4, Entropy = 0.92) and five-profile model (AIC = 1134.61, BIC = 1235.05, LMRT-LRT *p*-value = 0.75, Entropy = 0.90).

Profile Summaries at 3 and 7 Months. Table 2 (3 months) and Table 3 (7 months) shows the means and standard deviations of each LPA profile and FFSF episode at 3 months and 7 months based on additional infant characteristics. We conducted a 4 (class) x 3 (episode) repeated measures ANOVA to assess the main effects of class and FFSF episode using infant regulatory responses as the dependent variables to investigate further the profiles of each class.

3 Months

Significant main effects and interactions between classes. At 3 months there were significant differences between classes based on infant negative affect, distress regulation, arousal, resistance, and seek maintain behavior. Maternal behavior also differed significantly between classes based on engagement and tension/anxiety. Using groups comparisons to examine simple main effects, we found interactions between infant negative affect, distress regulation, and seek maintain behavior and FFSF episode at 3 months, as well as an interaction between maternal engagement and tension/anxiety and FFSF episode.

Class summaries at 3 months. The first and largest class (*n*=61, 66%) was labeled the *social-positive oriented* class because the parameters were most similar to the class of the same name identified by Barbosa and colleagues (2018). This class was characterized by consistently low negative affect across all three FFSF episodes, with higher scores on positive affect that decreased minimally during the still-face episode (see Figure 1). Regarding additional regulatory behaviors, these infants displayed significantly higher distress regulation abilities than the other classes, the lowest levels of resistance and highest "seek maintain" behaviors when compared with the other classes (see Table 2).

The second profile was labeled as the *classic still-face effect* class (*n*=19, 21%) because they expressed the classic still-face trajectory of high positive affect and low negative affect during the free play episode, with a decrease in positive affect and increase in negative affect during the still-face episode and an increase in positive affect during the reunion episodes, with some carryover from the still-face episode (Mesman et al., 2009; Tronick et al., 1978) (see Figure 2). This class displayed significantly lower levels of distress regulation abilities and "seek maintain" behaviors than the previous class, and higher levels of resistance behaviors (see Table 2).

The third profile was named the *self-comfort oriented* class (*n*=5, 5%), again based on the classifications by Barbosa and colleagues (2018). This class exhibited low levels of positive affect with a continuous decrease in positive affect across all three episodes of the FFSF. This group was also characterized by low negative affect during the still-face episodes and increase negative affect during the reunion episode (see Figure 3). They exhibited the second highest levels of distress regulation, meaning they were able to comfort themselves when distressed (see Table 2).

The fourth class was labeled the *distressed-inconsolable* class (*n*=7, 8%) and, as shown in Figure 4, was characterized by consistently high negative affect and low positive affect across all three FFSF episodes, and a decrease in positive affect during the still-face episode. This group displayed the significantly lowest levels of distress regulation and "seek maintain" behaviors, along with the highest levels of arousal and resistance behavior. These infants were unable to comfort themselves or use their caregiver to regulate their distress across the FFSF (see Table 2).

7 Months

Significant main effects and interactions between classes. At 7 months there were significant differences between classes based on infant distress regulation, resistance, and seek maintain behavior (see Table 3). Maternal behavior also differed significantly between classes based on engagement and tension/anxiety. Using groups comparisons to examine simple main effects, we found interactions between infant negative affect, distress regulation, and resistance and FFSF episode at 7 months.

Class summaries at 7 months. Four similar class profiles were found at 7 months, based again on Barbosa and colleagues (2018) classifications. The first and largest class (n=54, 66%) was labeled the *social-positive oriented* class and was characterized by consistently low negative affect across all three FFSF episodes, with higher scores on positive affect that decreased minimally during the still-face episode (see Figure 1). This class was also characterized by significantly higher levels of distress regulation behavior (see Table 3).

The second profile was labeled as the *classic still-face effect* class (n=15, 18%) because they expressed the classic still-face trajectory of high positive affect and low negative affect during the free play episode, with a decrease in positive affect and increase in negative affect during the still-face episode and an increase in positive affect during the reunion episodes, with some carryover from the still-face episode (Mesman et al., 2009; Tronick et al., 1978) (see Figure 2). This class of infants displayed the second highest levels of distress regulation and seek maintain behaviors, suggesting that when caregivers were available these infants were able to use them to regulate (see Table 3).

The third profile was named the *self-comfort oriented* class (n=7, 9%) and exhibited low levels of positive affect with a continuous decrease in positive affect across all three episodes of the FFSF. This group was also characterized by low negative affect during the still-face episodes and increase negative affect during the reunion episode (see Figure 3). This class also displayed the highest levels of resistance behavior overall (see Table 3).

The fourth class was labeled the *distressed-inconsolable* class (*n*=6, 7%) and, as shown in Figure 4, was characterized by consistently high negative affect and low positive affect across all three FFSF episodes, and a decrease in positive affect during the still-face episode. This class displayed the lowest levels of distress regulation and had the lowest levels of maternal engagement overall, with the highest levels of maternal tension/anxiety (see Table 3). These infants had caregivers who were unable to support them in regulating their distress.

Stability of Profiles Across 3 and 7 Months. In order to determine if infants maintained similar profiles across the 3- and 7-month timepoints, chi-square analyses were conducted and revealed no significant association between group membership at 3 months and 7 months, χ^2 (9, N = 86) = 9.55, p = .39. Of the 67 infants categorized as *social-positive oriented* at 3 months, 65% received the same categorization at 7 months. Of the 20 infants categorized as *classic still-face effect* at 3 months, 10% received the same categorization at 7 months. Of the five *self-comfort oriented* infants 20% received the same categorization at 7 months, and of the nine *distressed-inconsolable* infants 11% received the same categorization at 7 months (see Table 4).

Emotion Regulation in the FFSF Predicting the Security of Infant-Mother Attachment. To examine the association between the FFSF trajectory profiles and the security of the infant-mother attachment classification at 14 months, chi-square analyses were conducted looking at the association between each of the four emotion regulation classes in FFSF at 3 and 7 months, and the three attachment categories (ABC). No significant association was found χ^2 (9, n = 36) = 2.08, p = .912. Chi-square analyses also examined the association between the three attachment categories at 3 months and at 7 months, and found no significant association between attachment category at 3 months χ^2 (6, n = 77) = 6.42, *p* = .378, but a significant association at 7 months, χ^2 (6, *n* = 75) = 15.20, *p* = .019 (see Tables 5 and 6). Therefore, although a subset of the infants remained in the same classes, this stability did not predict attachment classifications. Classes at 7 months, however, did predict attachment classification at 14 months – meaning that attachment categories were more "solid" at 7 months.

We also tested whether there were associations between the emotion regulation profiles when we divided the attachment classifications into secure and insecure (B versus ACD), χ^2 (3, *n* = 36) = 2.93, *p* = .403, or organized versus disorganized (ABC versus D), χ^2 (3, N = 36) = 1.26, *p* = .739, but these analyses were all nonsignificant.

Discussion

Given the relevance of early emotion regulation for the formation of secure infant-mother attachment relationships and infant socioemotional development, the primary aim of this study was to examine individual differences in infant affective responses during the Face-to-Face Still-Face Paradigm at 3 and 7 months by using a person-centered approach to uncover latent profiles or classes of infants showing similar affective patterns across the FFSF. A second aim was to further delineate differences among the affective profiles by examining infant regulatory behaviors during the FFSF in order to label the overall pattern of affective and behavioral regulation used by infants in each class. Third, we examined whether maternal behavior differed across each class based on the theory that early infant emotion regulation is one of mutual regulation between infant and caregiver before being consolidated into self-regulatory strategies that emerge over the first year (Sameroff, 2009). Finally, we wanted to explore the stability or instability of these groups across 3 and 7-months, and whether these groups predicted attachment quality at 14 months.

Individual Differences in Infant Affect During the FFSF.

In contrast to many earlier studies using variable-centered approaches, the current study utilized a person-centered approach using Latent Profile Analysis in which we analyzed changes in infant positive and negative affective across the FFSF simultaneously in the same model, rather than independently, as a means of defining profiles of infant emotion regulation. In line with earlier studies taking a person-centered approach, we hypothesized that there would be at least three groups identified in line with previous person-centered studies having identified at least three groups and at most five (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018), with several finding a *social-positive oriented* group that remained positive throughout all episodes of the FFSF and had very low negative affect during the still-face episode, a *distressed-inconsolable* group that remained distressed across all episodes of the paradigm with little variation, and a *self-comfort oriented* group that demonstrated avoidant behaviors toward their caregiver, and an increase in negative affect during both the free-play and reunion episodes (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007). Only two of the four studies identified a *classic still-face effect* group characterized by a decrease in positive affect and an increase in negative affect during the still-face episode compared to the initial free play episode, with partial recovery during the reunion episode (Qu & Leerkes, 2018; Mesman et al., 2009; Papoušek, 2007).

The results from the current study are consistent with these previous studies, finding four groups with similar trajectories. The largest groups (67%) at both 3 and 7 months were similar to the *social-positive oriented* group identified by Barbosa and colleagues (2018), whose response patterns suggested that although these infants do register the non-responsivity of their mother and are confused by this change in interaction, they can successfully regulate their negative affect and seem to trust that their mother will ultimately resume her typical interaction style. This was the largest group found, as with previous studies (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007), and indicates that this profile may be a normative response to the FFSF. The second largest group found across the four studies was the *classic still-face effect* group (20%). This trajectory has been noted in the FFSF literature as the standard response for infants who have experienced sensitive caregiving (Mesman et al., 2009; Tronick et al., 1978), yet not all of the person-centered studies have found this classic effect for the majority of infants in the FFSF. According to the previous literature, these infants are distressed by the absence of interaction during the still-face episode because this experience is so far removed from their usual interaction with their caregiver. The use of their caregiver to regulate during the reunion episode indicates a regulated dyadic response (Tronick et al., 1978). The third group identified was the *distressed-inconsolable* group (9%) of infants who were distraught during the entire paradigm (Barbosa et al., 2018), and were unable to use their caregiver to regulate their emotions, underscoring that this group of infants may very well be dysregulated. The final group found was the *self-comfort oriented* group (5%), who demonstrated the opposite of the expected classic still-face response, where one would expect the withdrawal of the caregiver to be upsetting. Instead, this group was increasingly distressed when their caregiver was interacting with them (Barbosa et al., 2018), which also could indicate dysregulation and disruption in the caregiver-infant relationship.

Does Maternal Behavior in the FFSF Relate to Infant Profiles?

The current study found few differences in maternal care behavior among groups at 3 and 7 months. At 3 months, maternal engagement was significantly higher for the *social-positive oriented* class when compared with the *distressed-inconsolable* class. At 7 months, maternal engagement was significantly higher for the *social-positive oriented* class than the *distressed-inconsolable* class, and maternal tension/anxiety was significantly highest for the *distressed-inconsolable* class. This is surprising for many reasons, the first being that there is a robust literature linking maternal behavior and infant regulation (Sameroff 2009, Schore, 1994). Second, a multitude of maternal behavior variables were found to significantly differ between profiles in two previous person-centered studies (Montirosso et al., 2015; Papoušek, 2007). These non-significant findings could be due to the small group membership of our *self-comfort oriented* group (*N*=5) and our *distressed-inconsolable* group (*N*=9), leaving little room for variability and the power to detect class differences. This could also be reflective of our sample more generally, of which the majority of mothers tended to be highly sensitive and have low anxiety. It is also possible that the FFSF paradigm itself is not a complete picture of the parent-infant relationship, and instead a snapshot of a more fluctuating dynamic that could change based on time of day, whether the FFSF is done in the lab or the home, or if the infant has had a nap recently—controlling these variables with infant participants would be very difficult. Future research is needed to identify the link between maternal behavior and infant affective and behavioral regulation during the FFSF.

Group Stability in Longitudinal Analysis of Infant Behavior in the FFSF

We wanted to explore the stability or instability of the profiles at 3 and 7 months because according to Bowlby (1969), the 3 and 7-month timepoints span two different phases in the formation of attachment relationships in the infant's first two years. The second phase of attachment, defined by "discriminating sociability" occurs during the first 2-6 months of life and is when infants begin to show preference for specific adults, but have not yet developed separation anxiety. The third phase of attachment, aptly referred to as "attachment" begins at 6 months and extends to 24 months and is a time when attachment relationships become solidified. These differing relational phases are why we expected to see disparate groups at 3 and 7 months. Even though we found similar profiles at 3 and 7 months, we did not find stability in membership over this period of time suggesting that infants did indeed change how they responded to the episodes of the FFSF from 3 to 7 months in line with developmental expectations.

The majority of previous person-centered studies, however, only conducted the FFSF at one point during the first year. For instance, Papoušek (2007) conducted the FFSF at one timepoint with infants who were 2 to 6 months old, whereas Montirosso et al. (2015) conducted the paradigm at 4 months, and Qu and Leerkes (2018) at 6 months. Only one previous study explored the stability of profiles longitudinally at 3 and 9 months (Barbosa et al., 2018), finding three similar classes, *social-positive oriented*, *distressed-inconsolable*, and *self-comfort oriented*, with the majority of infants (88.3%, 84.2%, and 64.3, respectfully) remaining in the same groups across time. In the current study, we also identified the four similar groups at 3 and 7 months, but, unlike the previous study, we did not find that the same infants remained in the same group across time. This means that in our sample, the affective and regulatory patterns of infants during the FFSF at 3 and 7 months changed across time.

There are several possible explanations for the discrepancy between our findings and those of earlier studies. First, our study administered the FFSF at home, whereas Barbosa and colleagues (2018) conducted the FFSF with mother-infant dyads in the lab. It is possible that being in the lab versus being at home are two very different emotional experiences for infants—just being in the novel environment of the lab may be a stressor that the infant has to cope with in addition to the FFSF paradigm. This additional stressor may influence the behaviors infants use to regulate their affect.

Second, although the majority of infants in the Barbosa et al. 2018 study did remain in their same groups from 3-9 months, there were a subset of infants that did not. Perhaps this in itself—stable regulation patterns over time—is a factor of regulation. This could be positive, indicating a more organized attachment classification over time, or negative, indicating a lack of growth over time. We will need more longitudinal person-centered studies to ultimately parse these constructs.

Links Between FFSF Behaviors at 3 and 7 Months and Attachment Outcomes.

The final aim of this study was to determine whether the classes of infant emotion regulation at 3 and 7 months were associated with infant-mother attachment security at 14 months. Previous research has been inconsistent in this regard, with Braungart-Rieker et al., 2014 finding links between FFSF at 3 months and security of attachment at 12 months, but not at 7 months. One reason for these inconsistencies (see also Mesman et al., 2009) is because the majority of studies examining the link between the FFSF and attachment classification have utilized a variable-centered approach. In an effort to classify infant-mother attachment relationships in the strange situation procedure, researchers often look at the *pattern* of infants' affective and attachment-related behaviors (e.g., distress, approach, avoidance) across the multiple episodes of the SSP which are ultimately utilized to classify infants into the different groups: secure, insecure-avoidant, and insecure-ambivalent (Ainsworth et al., 1978). Latent profile analysis (LPA) inherently looks for patterns or profiles based on the similarities among infants in a group so a person-centered analysis of the FFSF reflects this more patterned approach to infant affect and behavior.

Of the four studies using person-centered analyses to identify classes of infants during the FFSF (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018), only Qu & Leerkes (2018) have linked their FFSF groups to attachment outcomes at 12 months using the SSP. They found their groups related to attachment behaviors on a continuous scale but results comparing their class and the attachment classifications were not reported. Their *highly distressed but regulating* group had low scores on their ratings of "negative" attachment variables such as avoidance and resistance, although the *resilient to distress* group was found to demonstrate the most "secure-like" behaviors, indicated by the lowest scores on the avoidance and resistance scales. Their *over-regulated* group demonstrated links with attachment avoidance, while their *under-regulated* group was linked to attachment resistance.

The current study did not find a significant association between the classes from the LPA at 3 and attachment classifications at 14 months, however we did find a significant association between LPA classes at 7 months and attachment outcomes at 14 months. This finding makes sense in the context of Bowlby's (1969) attachment phases. Seven months is the beginning of the "attachment" phase, when attachment classifications become solidified. Therefore, we would expect to see continuity in attachment categories from 7 months onward. There is still the question of the progression of attachment from 7-14 months, and whether these classifications are as solid at 7 months as they are at 14 months. This study does provide evidence, however, for Bowlby's attachment phases, and the use of the FFSF at 7 months in predicting attachment classifications at 14 months. This study is also the first to demonstrate that person-centered analyses of the FFSF relate to traditional attachment categories. Although additional variable-centered studies have found significant prediction from the FFSF conducted at 6 months in the first year to infant-mother attachment classifications at 12 months, the findings are anything but conclusive (Mesman, 2009), and more research using a person-centered approach would be worthwhile in the future.

Strengths and Limitations.

This study is unique in that it is a longitudinal person-centered analysis of the FFSF focused on modeling trajectories of both infant positive and negative affect simultaneously across the FFSF, and then determining whether maternal behavior differs across profiles, how these profiles are related over time in the first year, and whether they predict attachment outcomes. However, there are several limitations that should be noted. First, our LPA only considered positive and negative affect in creating group profiles. Although we later looked at how these affective groups differed on infants' regulatory behaviors and maternal caregiving behaviors, it is possible that if we included these additional variables into the LPA, we may have uncovered different groups. Our sample was relatively small compared to the recommended sample size for latent profile analysis (Tein, Coxe, & Cham, 2013), so we were limited as to the number of variables included in analyses and chose to start with positive and negative affect here because these variables are used consistently in almost every FFSF study. The FFSF was also administered in the home, versus the lab, providing a very different environment than lab studies. Infants may be more comfortable in their own homes and because of that, less stressed by the paradigm. There was also attrition across all three timepoints included in this study, which could have impacted the stability of group membership across 3 and 7 months and their association with attachment at 14 months.

Recommendations for Future Directions in FFSF Research.

There are three critical issues that should be considered in future research on the links between the FFSF from the Strange Situation Paradigm (SSP.) The first issue is that the FFSF has been administered at various timepoints across the first year of development, anywhere from days after birth to 9 months (Barbosa et al., 2018; Bigelow & Power, 2018). Because emotional development is so varied during the first 12 months, it is necessary to consider these studies in a developmental context, and perhaps pair these periods with the developmental phases of emotional development and attachment formation. For example, at 3 months infants express positive affect by smiling and cooing, while at 7 months positive affect may be demonstrated through babbling and gestures indicating social bids (Kopp, 1989), so infant behavior in the FFSF may not reflect similar underlying constructs across different timepoints in the first year. Therefore, future studies need to consider the meaning of infant affect and behavior in the FFSF from a developmental framework and acknowledge that affective profiles, even if similar on the surface, may not reflect the same underlying regulatory patterns given the rapid maturation of emotional responsiveness in the first year.

Another issue for research on the FFSF studies is that unlike the SSP, there is no standardized, validated, agreed-upon coding system for the assessment of infant affect and behavior in the FFSF. There appear to be as many different coding systems as there are studies utilizing the FFSF with both micro- (second by second) and macro-level (global ratings) coding schemes. Without a consistently reliable coding system that demonstrates both concurrent and predictive validity, it is difficult to know what is being measured, and how these different coding schemes compare across studies, making it nearly impossible to know if differences in results across studies are due to true differences in findings, or differences in measurement and analysis strategy. Because the SSP relies on a standard coding system that requires both training and consistent application to classifying infants, perhaps the most critical recommendation for the future is creating a systematic, psychometrically sound coding system for the FFSF so researchers can begin to have reliable and valid evidence for what the FFSF is actually measuring. Our significant findings provide beginning evidence that person-centered analyzes of the FFSF may be meaningfully related to attachment outcomes, but there are major issues to tackle before we can make any definitive conclusions about the relationship between these two constructs.

In sum, this study used person-centered analyses to find individual differences in infant affect during the FFSF. We found classes that resembled previous classes identified in the FFSF literature using person-centered analyses (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018). We did not find that maternal behavior predicted all of these classes, and our classes did not remain stable across 3 and 7 months. We did not find these classes at 3 months to be predictive of attachment quality at 14 months, but we did find a significant relationship between attachment outcomes and these classes at 7 months. These findings, taken together with the previous FFSF literature, leave us with more questions than answers of what the FFSF is measuring.

Figure 2.1. Positive and negative affect means and standard error at each episode of the Face-to-Face Still-Face Paradigm for the social-positive oriented group at 3 and 7 months.

Figure 2.2. Positive and negative affect means and standard error at each episode of the Face-to-Face Still-Face Paradigm for the classic still-face effect group at 3 and 7 months.

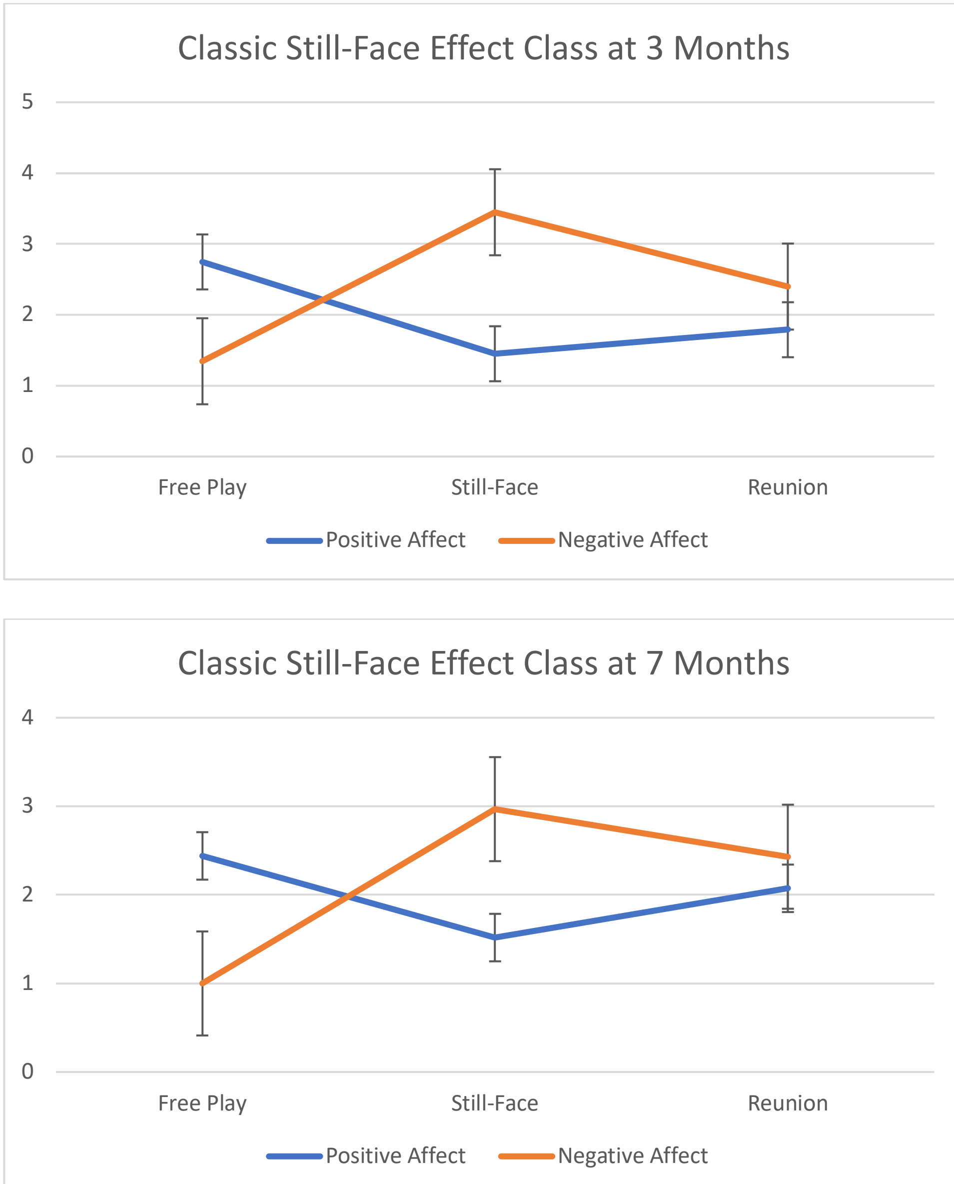
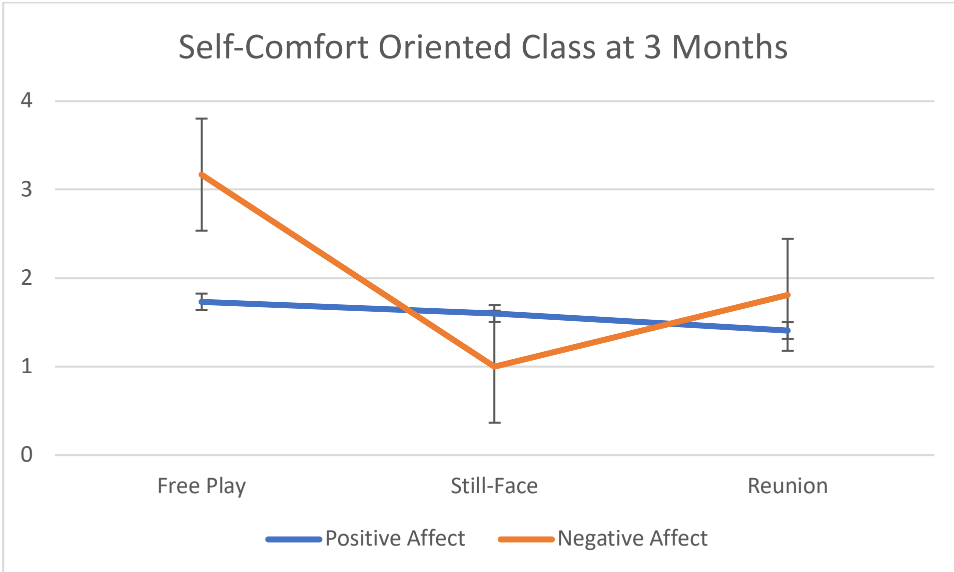


Figure 2.3. Positive and negative affect means and standard error at each episode of the Face-to-Face Still-Face Paradigm for the self-comfort oriented group at 3 and 7 months.



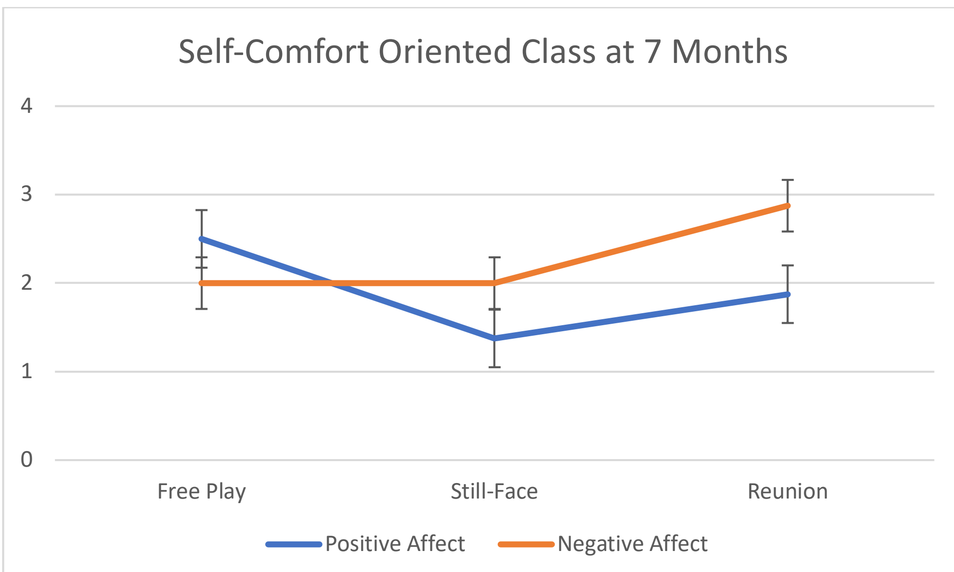


Figure 2.4. Positive and negative affect means and standard error at each episode of the Face-to-Face Still-Face Paradigm for the distressed-inconsolable group at 3 and 7 months.

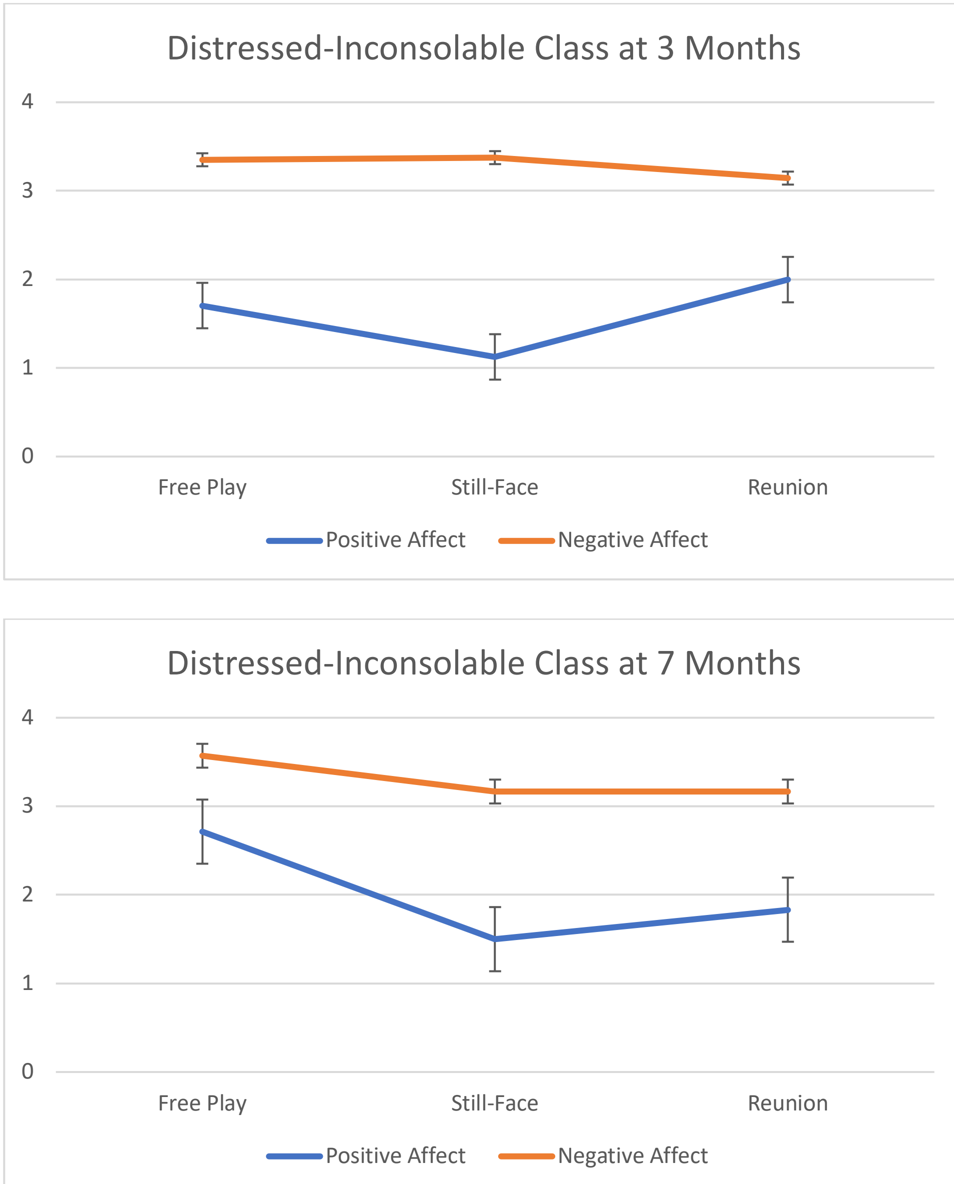


Table 2.1. *Sample characteristics. (N = 82)*

	Mean	SD
Maternal age	31.26	4.33
	%	
Maternal education		
High school or GED	1.22%	
Associate's degree	2.44%	
Vocational degree	1.22%	
Bachelor's degree	27.87%	
Master's degree	31.71%	
Doctorate	12.99%	
Other	15.85%	
Some college	7.32%	
Student	4.88%	
Marital status		
Married	96.34%	
Other	3.66%	
Employed		
Part-time	17.07%	
Full-time	57.32%	
Household income		
10,000-30,000	6.10%	
30,000-60,000	13.41%	
60,000-80,000	20.73%	
90,000-100,000	15.86%	
> 100,000	39.02%	
Infant gender	56.09% (male)	
Infant Race/Ethnicity		
Black	4.88%	
White	81.70%	
Asian or Pacific Islander	9.76%	
Other	1.22%	

Table 2.2. *Multiple Regressions Predicting Effects of LPA Class and FFSF Episode on Infant and Maternal Characteristics at 3 Months*

	LPA Class						**Episode**				
Variable	**Social-Positive (*N*=61)**	**Classic Still-Face (*N*=19)**	**Self-Comfort (*N*=5)**	**Distressed-Inconsolable (*N*=7)**	**F**	η_p^2	**Free Play**	**Still-Face**	**Reunion**	**F**	η_p^2
Infant	**M(SE)**	**M(SE)**	**M(SE)**	**M(SE)**			**M(SE)**	**M(SE)**	**M(SE)**		
Positive Affect	2.18(.09)	2.04(.16)	1.60(.32)	1.67(.27)	2.02	.12	2.55(.97)$_a$	1.58(.86)	2.11(.93)	13.40**	.13
Negative Affect	1.18(.05)$_a$	2.40(.09)$_b$	2.00(.18)$_c$	3.27(.15)$_d$	93.93**	.76	1.42(.80)	1.77(1.13)	1.74(1.11)	.14	.00
Distress Regulation	3.85(.05)$_a$	2.67(.08)$_b$	3.07(.17)$_c$	1.81(.14)$_d$	97.59**	.77	3.63(.75)	3.27(1.07)	3.30(1.08)	1.48	.02
Arousal	3.03(.05)$_a$	3.12(.09)	3.00(.17)	3.4(.14)$_b$	3.87**	.12	2.92(.47)$_a$	3.22(.61)$_b$	3.12(.47)	3.19*	.04
Self-Object	2.53(.09)	2.28(.16)	2.27(.32)	2.33(.27)	.80	.03	2.25(.98)	2.85(.81)$_a$	2.25(.96)	7.39**	.08
Avoidance	2.51(.08)	2.43(.14)	2.33(.28)	2.71(.24)	.48	.02	2.38(.85)	2.70(.78)$_a$	2.43(.81)$_b$	5.38**	.06
Resistance	1.51(.08)$_a$	2.30(.14)$_b$	1.93(.28)	2.38(.24)$_b$	10.93**	.27	1.55(.82)	1.95(1.03)	1.82(1.04)	.53	.01
Seek Maintain	3.15(.06)$_a$	2.77(.11)$_b$	2.87(.21)	2.48(.18)$_b$	6.48**	.18	3.20(.55)$_a$	2.86(.74)$_b$	2.97(.73)	3.12*	.03
Mother											
Engagement	3.61(.09)$_a$	3.13(.16)	3.50(.30)	2.86(.26)$_b$	4.24**	.13	3.57(.75)$_a$	n/a	3.32(.94)$_b$	7.35**	.08
Sensitivity	n/a	3.00(.29)	2.50(.29)	3.17(.17)	2.40	.55	3.20(.45)	n/a	2.80(.45)	2.40	.55
Positive Affect	3.23(.06)	3.03(.12)	3.20(.22)	2.71(.19)	2.63	.08	3.19(.56)	n/a	3.10(.58)	2.98	.03
Tension/Anxiety	1.11(.04)	1.29(.08)	1.40(.15)	1.07(.13)	2.48	.12	1.12(.33)	n/a	1.20(.45)	3.68	.04
Intrusiveness	2.71(.09)	2.42(.16)	2.20(.30)	2.29(.26)	2.10	.07	2.52(.83)	n/a	2.66(.76)	2.84	.03

Note: Subscripts denote significant differences between classes and/or episodes.
* $p < .05$, ** $p < .001$

Table 2.3. *Infant Characteristics at 3 Months * Episode Interaction at 3 Months*

	LPA Class											
Variable	Social-Positive			Classic Still-Face			Self-Comfort			Distressed-Inconsolable		
	Free Play	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**
Negative Affect	1.08(.28)$_{1}$	1.10(.30)$_{1}$	1.36(.82)$_{1}$	1.35(.49)$_{a2}$	3.45(.51)$_{b2}$	2.40(1.27)$_{c2}$	3.20(.45)$_{a3}$	1.00(.00)$_{b1}$	1.80(1.30)$_{b12}$	3.29(.49)$_{3}$	3.43(.54)$_{2}$	3.14(.90)$_{2}$
Distress Regulation	3.93(.25)$_{1}$	3.92(.28)$_{1}$	3.70(.74)$_{1}$	3.65(.59)$_{a1}$	1.80(.52)$_{b2}$	2.55(1.28)$_{c2}$	2.140(1.14)$_{a2}$	3.60(.89)$_{b1}$	3.20(1.30)	1.86(.38)$_{2}$	1.57(.54)$_{2}$	2.00(.82)$_{2}$
Resistance	1.36(.66)$_{1}$	1.62(.78)$_{1}$	1.56(.83)$_{1}$	1.63(.83)$_{a1}$	3.00(1.11)$_{1}$	2.37(1.21)$_{2}$	2.20(.84)	1.40(.55)$_{2}$	2.20(1.30)	2.57(1.13)$_{2}$	2.29(1.11)$_{12}$	2.29(1.38)
Seek Maintain	3.28(.55)$_{1}$	3.08(.61)$_{13}$	3.10(.57)	3.26(.56)$_{a1}$	2.32(.67)$_{23}$	2.74(.87)	2.80(.84)$_{12}$	3.00(.71)$_{3}$	2.80(1.30)	2.57(.54)$_{2}$	2.29(.95)$_{23}$	2.57(.98)

Note: Alphabetic subscripts denote significant differences within the same LPA class, while numeric subscripts denote significant differences between classes across episodes.

Table 2.4. *Maternal Characteristics * Episode Interaction at 3 Months*

	LPA Class							
Variable	**Social-Positive**		**Classic Still-Face**		**Self-Comfort**		**Distressed-Inconsolable**	
	Free Play	**Reunion**	**Free Play**	**Reunion**	**Free Play**	**Reunion**	**Free Play**	**Reunion**
Engagement	3.67(.66)	$3.55(.72)_2$	$3.47(.91)_a$	$2.79(1.13)_1$	3.40(.89)	3.60(.89)	3.14(.90)	$2.57(1.27)_2$
Tension/Anxiety	1.12(.32)	$1.10(.30)_1$	$1.16(.38)_a$	$1.42(.61)_2$	$1.20(.45)_a$	1.60(.89)	1.00(.33)	1.14(.38)

Note: Alphabetic subscripts denote significant differences within the same LPA class, while numeric subscripts denote significant differences between classes across episodes.

Table 2.5. *Multiple Regressions Predicting Effects of LPA Class and FFSF Episode on Infant and Maternal Characteristics at 7 Months*

	LPA Class						**Episode**				
Variable	**Social-Positive (N=54)**	**Classic Still-Face (N=15)**	**Self-Comfort (N=7)**	**Distressed-Inconsolable (N=6)**	**F**	η_p^2	**Free Play**	**Still-Face**	**Reunion**	**F**	η_p^2
Infant	**M(SE)**	**M(SE)**	**M(SE)**	**M(SE)**			**M(SE)**	**M(SE)**	**M(SE)**		
Positive Affect	2.18(.08)	1.93(.15)	1.92(.20)	2.00(.23)	1.12	.04	2.54(.86)$_a$	1.42(.70)$_b$	2.33(.90)$_c$	24.46**	.24
Negative Affect	1.23(.05)$_a$	2.16(.10)$_b$	2.29(.14)$_a$	3.28(.16)$_c$	71.16**	.73	1.28(.71)$_a$	1.68(1.01)	1.99(1.16)	10.14**	.12
Distress Regulation	3.85(.05)$_a$	3.00(.09)$_b$	2.71(.13)$_a$	2.00(.14)$_c$	85.55**	.77	3.77(.62)$_a$	3.39(.93)$_b$	3.22(1.01)$_b$	14.91**	.16
Self-Object	3.23(.06)	3.09(.12)	3.13(.17)	3.06(.19)	.55	.02	3.06(.65)	3.65(.55)	2.83(.78)$_a$	25.80**	.25
Avoidance	3.04(.05)	2.84(.08)	2.83(.12)	3.11(.14)	2.08	.07	2.95(.44)	3.20(.44)$_a$	2.81(.57)$_c$	5.49**	.07
Resistance	1.43(.08)$_a$	1.93(.15)$_b$	2.79(.21)$_c$	2.56(.24)$_{ac}$	18.07**	.41	1.46(.87)$_a$	1.87(1.03)$_{bc}$	1.88(1.08)$_c$	6.25**	.07
Seek Maintain	2.85(.06)	2.78(.11)$_a$	2.71(.14)	2.33(.17)$_b$	3.05*	.10	2.87(.58)	2.61(.60)	2.88(.59)	1.42	.02
Mother											
Engagement	3.34(.09)	2.93(.17)$_a$	3.13(.23)	2.42(.26)$_b$	4.59**	.15	3.31(.76)$_a$	n/a	3.05(.89)$_b$	6.77*	.08
Sensitivity	2.50(.35)	n/a	3.00(.50)	3.00(.25)	.71	.26	3.00(.58)	n/a	2.71(.49)	2.29	.36
Positive Affect	3.22(.08)	3.07(.15)	3.31(.20)	2.92(.23)	.87	.03	3.19(.55)	n/a	3.17(.67)	.21	.00
Tension/Anxiety	1.14(.09)	1.14(.05)$_a$	1.13(.12)	1.58(.14)$_b$	3.19*	.11	1.15(.84)	n/a	1.20(.43)	1.11	.01
Intrusiveness	2.87(.17)	2.87(.17)	2.94(.23)	3.08(.27)	.29	.01	2.83(.71)	n/a	2.90(.74)	1.00	.01

Note: Alphabetic subscripts denote significant differences between classes and/or episodes.
* $p < .05$, ** $p < .001$

*Table 2.6. Infant Characteristics * Episode Interaction at 7 Months*

	LPA Class											
Variable	**Social-Positive**			**Classic Still-Face**			**Self-Comfort**			**Distressed-Inconsolable**		
	Free Play	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**	**Free Play**	**Still-Face**	**Reunion**
Negative Affect	1.00(.00)$_{1}$	1.09(.30)$_{1}$	1.58(.97)$_{a1}$	1.00(.00)$_{a1}$	3.00(.54)$_{2}$	2.47(1.19)	2.00(.00)$_{2}$	2.00(1.07)$_{3}$	2.97(.99)	3.50(.55)$_{3}$	3.17(1.17)$_{2}$	3.17(1.17)
Distress Regulation	4.00(00)$_{a}$	3.93(.26)$_{1}$	3.61(.76)$_{b1}$	4.00(00)$_{a}$	2.07(.59)$_{b2}$	2.93(.96)c$_{2}$	2.86(.38)$_{1}$	3.14(.90)a$_{3}$	2.14(.90)$_{b2}$	2.17(.98)$_{2}$	2.17(.98)$_{2}$	1.67(.52)$_{3}$
Resistance	1.28(.74)$_{1}$	1.46(.84)$_{1}$	1.56(.93)$_{13}$	1.13(.52)$_{a1}$	2.80(.78)$_{b2}$	1.87(1.06)$_{c3}$	2.50(1.07)$_{a2}$	2.50(1.07)$_{2}$	3.38(.52)$_{b24}$	2.50(.84)$_{2}$	2.33(1.21)	2.83(.75)$_{234}$

Note: Alphabetic subscripts denote significant differences within the same LPA class, while numeric subscripts denote significant differences between classes across episodes.

Table 2.7. *Stability of LPA Classes at 3 and 7 Months.*

	Social-Positive (7 months)	**Classic Still-Face (7 months)**	**Self-Comfort (7 months)**	**Distressed-Inconsolable (7 months)**
Social-Positive (3 months)	39	10	7	3
Classic Still-Face (3 months)	10	2	0	3
Self-Comfort (3 months)	2	2	1	0
Distressed-Inconsolable (3 months)	4	2	0	1

Table 2.8. *LPA Classes and Attachment Categories at 3 Months.*

	Secure	Ambivalent	Avoidant
Social-Positive	32	7	12
Classic Still-Face	8	4	3
Self-Comfort	2	2	0
Distressed-Inconsolable	5	2	0

Table 2.9. *LPA Classes and Attachment Categories at 7 Months.*

	Secure	**Ambivalent**	**Avoidant**
Social-Positive	28	7	16
Classic Still-Face	8	5	0
Self-Comfort	6	0	0
Distressed-Inconsolable	1	2	2

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CHAPTER 3: (Study 2) More than meets the eye: The neural development of emotion face processing during infancy

With limited visual and motor skills and an inability to care for themselves, the relationship between caregiver and infant is central to the infant's survival (Grossmann, 2010). Therefore, it is no surprise that infant brains are specialized to process faces and the first expressions they can decipher are those of their mother (Field et al., 1984). Although at first, infants may discriminate between emotion faces based on structural information, such as facial features (Kestenbaum & Nelson, 1990), they later attach affective meaning to facial expressions and utilize this emergent emotional understanding to process social cues as well as to regulate their own emotional responses (Grossmann, Striano, & Friederici, 2007). The process of imbuing facial expressions with emotional meaning centers on the development of the amygdala-medial prefrontal cortex (mPFC) circuit (Tottenham, 2015).

The prefrontal cortex (PFC) is the anterior portion of the frontal lobe and is primarily responsible for the most complex brain processes. The PFC sends and receives information from almost all other structures in the brain and organizes thoughts and behaviors in an attempt to accomplish internal goals (Miller & Cohen, 2001). In order to regulate emotions, the PFC exerts inhibitory control on the amygdala through the mPFC, the area of the cortex directly connected to the amygdala (Urry et al., 2006). The amygdala pairs environmental input with emotional responses, such as fear in response to loud noises (Cardinal, Parkinson, Hall, & Everitt, 2002). This pairing is how individuals learn to categorize stimuli as inducing various emotions—both negative and positive (Tottenham, 2010). Over time, the mPFC and the amygdala become part of a larger network of emotion processing and regulation. Temperament and quality of maternal interaction are two factors that have been found to influence infant responsivity to emotion face processing (Calder, Ewbank, & Passamonti, 2011; Rajhans, Missana, Krol, & Grossmann, 2015; Tottenham, 2014). The primary goal of the current study was to identify the underlying neural mechanisms involved in emotion face processing in infants ages 6-8 months, and then examine the relations between neural responsivity to various emotion faces and both infant temperament and the quality of the mother-infant relationship.

Evidence of the Neural Underpinnings of Emotion Face Processing

A handful of electroencephalogram (EEG) studies have examined the neural development of emotion face processing, and how emotion processing may differ as a function of infant temperament and the early caregiving context. Although EEG research is unable to pinpoint the exact brain structures involved in emotion face processing due to constraints in temporal resolution, these studies reveal striking evidence about the impact of individual differences in infant emotional development and neural activation.

EEG studies focusing on the temperamental correlates of infant neurological activation to emotion faces have found that infants rated highly on negative emotionality showed greater reactivity to happy faces than fearful faces, possibly relating to a lack of habituation to nonthreatening stimuli (Martinos, Matheson, & De Haan, 2012). Similarly, another EEG study examining the association between maternal mood and infant emotion face processing demonstrated that when the reactivity of infants of depressed and non-depressed mothers was compared, infants of non-depressed mothers demonstrated more frontal activation during the sad versus happy trials, one explanation being that sad faces were less familiar to the infants of non-depressed mothers (Field, Pickens, Fox, Gonzalez, & Nawrocki, 1998). A third study demonstrated that infants raised by highly positive mothers are more reactive to fearful faces than happy faces (de Haan, Belsky, Reid, Volein, & Johnson, 2004). The results of these studies suggest that infants are more reactive to emotional expressions that are the most novel to their actual experiences.

Another EEG study, however, demonstrated the opposite activation pattern. Infants raised in extreme circumstances with very little adult caregiving, such as institutionalization, displayed greater reactivity to fearful faces versus sad and happy faces. With infants who experienced more traditional caregiving (i.e. being raised within some type of family unit), greater activation to sad expressions versus fearful expressions was found (Parker & Nelson, 2005). In contrast to previous studies, these groups of infants were more reactive to familiar emotions. These results may be due to an overly reactive amygdala in infants who have experienced institutionalization, as they likely have had more reason to identify and respond to fear, suggesting that brain responses may be emotion specific and vary based on population.

The conflicting results of these studies demonstrate that there is still much to be learned about the development of the infant emotional brain and the mechanisms that induce brain activation. One issue may be how difficult it is to examine multiple aspects of the infant's social environment in a laboratory setting. For example, one functional Near Infrared Spectroscopy (fNIRS) study examined the relationship between infant fearfulness and maternal empathy and infant brain activation to emotional body expressions. An interaction effect was found, such that highly fearful infants with empathic mothers showed decreased brain activation to fearful body expressions in relation to happy body expressions (Rajhans, Missana, Krol, and Grossmann, 2015). These results suggest that more research is needed on the context of brain activation within the social environment.

fNIRS: A Novel Method for Imaging Infant Brain Activation

At present, the advent of Functional Near-Infrared Spectroscopy, or fNIRS, a non-invasive neuroimaging technology has allowed researchers an additional and critical tool to investigate the development of the prefrontal cortex during infancy. Other forms of imaging technology, such as functional magnetic resonance imaging, or fMRI, which requires the infant to be very still or sleeping, are either too invasive or too limiting of movement to permit exploration of infant brain activation to emotional experiences. fNIRS can accommodate movement and allows infants to sit upright, creating a much more normative environment in which to assess brain responses to social and emotional stimuli (Grossman, 2013). fNIRS is also similar to an EEG set-up, in that it involves placing a cap on the infant's head but utilizes the Blood Oxygenation Level Dependent (BOLD) Signal like fMRI, which allows researchers to target specific Regions of Interest (ROI) with respect to brain structures (e.g., mPFC).

In a recent study, Ravicz, Perdue, Westerlund, Vanderwert, & Nelson (2015) utilized fNIRS to examine differences in the hemodynamic responses to happy, fearful, and angry faces based on the infant's temperamental characteristics. Twenty-four 7-month-old infants were divided into temperament-based groups based on high or low scores of negative emotionality (NE), surgency/extraversion (S/E), and orienting/regulating (O/R). When examining the PFC as a whole, these authors found that infants with lower S/E or NE scores demonstrated greater activation in response to the happy face trials. Low NE infants also showed greater responsivity in the left hemisphere of the PFC during the happy face trials. These results provided initial support for the use of fNIRS to examine individual differences in infant neural responses to emotion faces and potential underlying neural mechanisms. The current study was an attempt to replicate portions of Ravicz et al., (2015) utilizing happy, sad, and angry faces rather than happy, fearful, and angry faces in line with our interest in looking at the links between infant brain activation to emotion faces and maternal characteristics such as maternal depressive symptomatology, as well as infant temperamental characteristics and the quality of the maternal caregiving environment.

The Current Study

The current study focused on defining further the underlying neural activation in regions of the mPFC as it is related to emotion face processing for 7-month-old infants. We chose to focus on the mPFC based on previous infant fNIRS studies finding increased activation in the mPFC during emotional processing tasks, that also focused on 7-month-old infants (Naoi et al., 2012; Saito et al., 2007; Schore, 1994; Tottenham, 2015). The overall purpose of this study was to investigate the neural signature of emotion face processing among infants of varying temperaments and caregiving environments. The first aim was to focus on the mPFC to explore the neural correlates of infant emotion face processing. We hypothesized that the mPFC is the neural correlate of emotion face processing during infancy and will be significantly activated during the emotion faces task.

The second aim was to examine whether brain activation during the emotion face processing task differed for infants with different temperaments. Based on the results of the majority of emotion face processing studies that found infants are more activated by emotions most novel to their experiences (Ravicz et al., 2015; Martinos, Matheson, & de Haan, 2012; de Haan et al., 2004; Field et al., 1998), we hypothesized that infants high on negative emotionality would demonstrate greater brain activation to happy faces than infants rated low on negative emotionality, whereas infants who score highly on surgency/extraversion will display greater brain activation to the sad and angry faces.

The third aim was to investigate the impact on brain activations for infants in highly stressful caregiving environments. We hypothesized greater mPFC activation during presentations of happy faces than sad faces because infants of highly stressed mothers have more than likely experienced more negative emotions during mother-infant interactions than infants of low stressed mothers, and hence, have more familiarity with negative emotions (Feldman et al., 2009). These infants will be tested at 7 months, a critical time in the development of their emotion regulation skills, and from previous research we know that infants with high negative emotionality and highly stressed mothers are less adept at regulating their emotions over time (Kovacs, 2004).

Methods

Participants

Sixteen 6- to 9-month-old infants and their mothers participated in the study. Seven additional infants were also recruited and tested, but were excluded from the study for various reasons including movement artifacts ($n = 4$), equipment failure ($n = 1$), or failure to complete the task ($n = 2$). This attrition rate is comparable to previous infant studies (Lloyd-Fox et al., 2010). All infants were full-term without histories of medical complications or neurological problems. Mothers provided informed consent prior to participation in the study, and the University of Michigan Institutional Review Board for Behavioral and Health Sciences approved the protocol (HUM00115290). Mother-infant dyads were recruited from UMclinicalstudies.org, the Women's Mental Health Registry from the Department of Obstetrics and Gynecology, as well as through flyers at local libraries, businesses, parks, and Women, Infants & Children (WIC) offices. See Table 1 for additional participant characteristics.

Session Overview

Mothers arrived with their infants to a university laboratory and were escorted to a child friendly waiting area by the experimenter who described the sequence of events that would take place during the visit. The mother then read and signed both consent forms (mother and infant) and then completed two short surveys: one that assessed infant temperament and another that evaluated maternal stress. Another member of the research staff engaged the infant during this time to allow the infant time to become comfortable within the lab setting; infant head measurements were also taken during this time. In concordance with the 10-20 international system (Jasper, 1958) the infant's head circumference and distance between inion and nasion were noted for correct cap placement.

The mother and infant were then directed to the fNIRS room for the emotion faces task. The infant sat on the mother's lap during the entire task, including cap placement (Figures 1 and 2). The fNIRS cap was placed on the infant's head according to the measurements previously recorded. Video-recordings (iPad mini version 2, Apple, Cupertino, CA). of the entire task were recorded to ensure that cap and optodes were covering the correct brain regions throughout the task and that the infants were looking at the stimuli at a rate of greater than 50% of the task (Ravicz et al., 2015). The mother was asked to sit silently and to try not to move or talk to the infant during the activity.

Emotion Faces Task

In order to assess emotion face processing, infants were shown a series of pictures of women with happy, sad, or angry facial expressions chosen from the NimStim Face Stimulus Set

(Tottenham et al., 2009). Each trial included three short blocks of each emotion, with five different women expressing the same emotion shown for one second, for a total of five seconds. Eight seconds of black and white shapes including a square, circle, star, and triangle, were shown in between each emotion block. Therefore, each trial contained fifteen seconds of face pictures with a randomly generated 200-400ms inter-stimulus time, and twenty-four seconds of shapes. Emotions were pseudo-randomized across the task (random, but in the same order for each participant). In total, there were ten trials of each emotional type resulting in 30 trials altogether (Figure 3). The faces were presented using the E-Prime Application Suite for Psychology (E-Prime 2.0, Psychology Software Tools, Sharpsburg, PA, USA). The session was terminated if the infant became too upset or the mother requested to discontinue, which she was told she could do at any time. This set of stimuli is a modification of the methods and procedures of a previous fNIRS study by Ravicz, Perdue, Westerlund, Vanderwert, & Nelson (2015), in which they utilized happy, fearful, and angry expressions in a block design format. Our focus was on happy, sad, and angry faces in the current study because we had initially planned on recruiting both depressed and nondepressed mothers, but it proved difficult to screen for depressive symptoms in our attempts to recruit mothers.

fNIRS Data Acquisition

During the emotion faces task, a continuous wave fNIRS system (CW6; TechEn Inc., Milford, MA) was used to record the hemodynamic responses of the mPFC. Two wavelengths, 690 and 830 nm, were used during data collection with a sampling rate of 50 Hz. Fiber optic cables were used to disseminate near-infrared light to a custom-designed Easycap (GmbH, Herrsching am Ammersee, Germany) made for this study and adjusted using a velcro chin strap for each infant's head size. The cap was designed using three source- and five detector-optodes placed 2.5 inches apart forming an 9-channel array (grommets, TechEn, Inc. Milford, MA; see Figure 2). The array was calculated using the 10-20 international system (Jasper, 1958) and channels covered the C1-17 landmarks to capture our region of interest (Brodmann's areas (BA) 10, see Figure 1) The cables were connected to the cap before being placed on the infant's head at the beginning of the emotion faces task.

Brain regions. Brain regions were estimated using a Polhemus Patriot 6DOF Digitizer on a mannequin head. The resulting coordinates were put into AtlasViewerGUI (Aasted et al., 2015), through MATLAB to render the brain measurements in Montreal Neurological Institute (MNI) stereotactic space. These coordinates were then partitioned into 1000 voxel points that identified the midpoint between each source and detector optode (see Figure 1) and rendered them on a 3D brain template (https://irc.cchmc.org/software/pedbrain.php). To ensure the optodes would be placed to accurately capture our regions of interest (ROI), these voxel points were converted to BA's using xjView database in Matlab (http://www.alivelearn.net/xjview).

Data processing. Inclusion criteria were based on several factors, including percentage of the emotion faces task completed, percentage of time the video indicated that the infant was looking at the screen, the strength of signal, and motion artifacts. Motion artifacts are artificial signals that resulted from the participant moving during the task, which was the major reason participant data were not included in the final analyses. To examine the quality of the data, Homer2 and NIRS Toolbox (Santosa, Fishburn, & Huppert, 2018) were used to assess each channel, as well as to convert the raw time course data into units of optical density.

Self-Report Measures

Infant temperament. Infant temperament was measured using the Revised Infant Behavior Questionnaire Short Form (Putnam, Helbig, Garstein, Rothbart and Leerkes, 2014), a caregiver report instrument with items designed to describe specific behaviors in infants ages 3 to 12 months. Mothers were asked to respond to 36 items based on their infant's behavior during the previous week. This questionnaire consists of 14 subscales that load onto three different temperament factors (Gartstein & Rothbart, 2003): (1) *Surgency/Extraversion (S/E),,* which includes activity level, vocal reactivity, smiling and laughing, high intensity pleasure, perceptual sensitivity, and approach; (2) *Negative Emotionality (NE)*, which includes subscales of fear, distress to limitations, sadness and falling reactivity; and (3) *Orienting/Regulation (O/R),* which includes soothability, duration of orienting, cuddliness, and low intensity pleasure. Items were averaged across scales to create mean scores. The reliability and validity of this instrument have been documented with Cronbach's alpha's ranging from .77-.96 (Gartstein & Rothbart, 2003).

Parenting stress index. Parenting stress was measured with the 36-item Parenting Stress Index-Short Form (Abidin, 1995), a widely used assessment of parental stress that has been used with mothers of infants (Beebe, Casey, & Pinto-Martin). The total stress score ($\alpha = .84$) is used to assess an overall level of parenting stress with four subscales; (1) *Parental Distress* ($\alpha = .85$) – the distress the individual feels in relations to their identity as a parent, (e.g. 'I feel trapped by my responsibilities as a parent'); (2) *Parental-Child Dysfunctional Interaction* ($\alpha = .68$) – the parents' views of the child as not meeting expectations or displaying positive behaviors in response to the parent (e.g. 'My child rarely does things for me that make me feel good'); (3) *Difficult Child* ($\alpha = .78$) – perceptions of child's demandingness and compliance (e.g. 'My child makes more demands on me than most children'). Higher scores indicate greater levels of stress, and a score lower than ten on the defensive responding scale indicates insincerity (Abidin, 1995).

Data Analysis

We first conducted preliminary analyses to determine whether we needed to control for any of our demographic variables (i.e., age, maternal education, household income, race/ethnicity, gender, and marital status) in our analyses. There were no significant correlations with the demographic variables so these variables were not included in further analyses.

Participant fNIRS data included in the study then went through preprocessing which included examining two major sources of noise that influence fNIRS data—physiological signals unrelated to brain responses and motion artifacts (Barker, Aarabi, & Huppert, 2013). Motion artifacts are especially problematic with infants, who are unable to remain still for very long. Raw data were exported from the Techen fNIRS machine to Matlab (Mathworks, Inc., 2016) and Homer2 (Barker, Aarabi, & Huppert, 2013) was used to inspect the quality of the data and label each condition of the task by stimulus. NIRS Toolbox (Santosa, Fishburn, & Huppert, 2018) was then used to convert the data into units of optical density (OD). A NIRS Toolbox algorithm was used to detect motion artifacts by channel. This function identifies data points exceeding an experimenter-set threshold in amplitude and standard deviation within a given period of time and marks them as outside these parameters. The values in this study were *AMPThresh* = 1, *SDThresh* = 50, *tMotion* = 0.5, and *tMask* = 1 (Cooper et al., 2012; Scholkmann et al., 2010). Spline based motion correction was then used to correct the previously identified motion artifacts; interpolation parameter = 0.99 (Scholkmann et al., 2010). The data were then transformed into hemoglobin concentration changes using the modified Beer-Lambert law. A general linear model (Huppert, Karim, Lin, Alqahtani, Greenspan, & Sparto, 2016) was used for each task condition to calculate the response signal strength (β) of the hemoglobin data, including HbO, HbR, and HbT.

Data were then exported to IBM SPSS Statistics v. 25 software. Paired samples *t-tests* were performed in order to determine if there was a statistically significant difference between total β values of each emotion face condition. Correlations were then used to probe significant associations between total brain activation during each condition and the various temperament and maternal stress scales. Multiple regressions were then used to identify significant temperament and maternal stress predictors of brain activation.

Results

Descriptive Statistics and Correlations

To examine the main effect of emotion faces condition, paired samples *t-tests* were utilized to examine significant differences in HbO and HbR activation between the three emotion faces conditions, which proved to be non-significant (see Figure 3). Then, correlations between temperament, maternal stress and total activation of HbO and HbR during each condition were performed to explore significant associations between infant temperament, maternal stress, and brain activation. The total stress scale of the PSI-SF was significantly positively associated with HbR activation during both the angry and sad emotion faces conditions. The parent-child dysfunctional interaction subscale of the PSI-SF was significantly positively associated with HbR activation during the happy faces condition. Negative emotionality, a subscale of the IBQ-R-SF, was significantly associated with all conditions of the task, and changes in both HbO (negative correlations) and HbR (positive correlations) activation and was most strongly correlated with the happy faces condition and both HbR and HbO (see Table 3).

Predicting Brain Activation from Infant and Maternal Characteristics

In order to examine whether infant temperament and maternal stress were unique predictors of infant brain activation during the emotion face processing task we utilized multiple regressions and focused our analyses on total HbO and HbR activation. Given the exploratory nature of this study we did not correct for multiple comparisons. Both maternal reports of total stress and the parent-child dysfunctional interaction scale from the PSI-SF and maternal reports of infant temperament from the IBQ-R-SF were included in multiple regression analyses, and all variables were centered prior to the inclusion in the analyses. The negative emotionality scale from the IBQ-R-SF and the parent-child dysfunctional interaction scale from the PSI-SF were found to be unique predictors of HbR activation during the happy faces condition in the model. Total stress combined with negative emotionality were also examined as predictors of HbR activation during the sad and angry faces conditions. Only total stress was found to be a unique predictor in both models (Table 4).

Discussion

Humans are an altricial species, which means that infants are vulnerable when born and require the constant care and attention of a caregiver to survive. Just as hatchlings cannot survive outside the nest and rely on their mothers for food and warmth, human infants rely on their caregivers to provide them with safety and physiological co-regulation (Tottenham, 2012; Sameroff, 2009). During the first year, the infant brain matures at a rapid pace, and the quality of early caregiving plays an essential role in facilitating growth, ultimately influencing how an individual will respond to novel and/or stressful situations throughout life (Schore, 2001). Although the long-term effects of environmental input on the brain can be observed both behaviorally and through neuroimaging, we still know little about how the brain processes emotions in infancy. This study augments the current literature by providing contextual information about the early caregiving environment and infant temperament to an understanding of emotion face processing by human infants.

Our first goal focused on our hypothesis that the main region of interest involved in emotion face processing is the mPFC. Previous studies have focused on this area and its connection with social-emotional processing (Grossmann, 2013), and this study confirmed significant brain activation in the mPFC during the emotion faces task. The mPFC as a whole did not respond cohesively to the task, and different regions of the mPFC activated during each emotion condition (see Figure 4). This may speak to the complexity of the mPFC as a whole, and that different regions of this structure are involved in different aspects of emotion processing.

Regarding our hypotheses that infant temperament and level of maternal stress would influence brain activation, we did find these factors to be associated with significant changes in HbO and HbR. The total stress scale of the Parenting Stress Index was significantly positively associated with HbR activation during the sad and angry faces conditions. The parent-child dysfunctional interaction subscale was significantly positively associated with HbR activation during the happy faces condition. This demonstrates that maternal stress generally, as well as more nuanced subscales are related to infant brain activation (see Table 3). Multiple regression analyses showed that although both total stress and negative emotionality were correlated with the sad and angry faces HbR condition, negative emotionality did not add statistical significance to the model, while negative emotionality and parent-child dysfunctional interaction both were significant when predicting happy face HbR activation (see Table 4).

High parent-child dysfunctional interaction being related to increased brain activation during the happy faces condition was consistent with our hypothesis that infant brain regions will be more activated by novel experiences (i.e. infants with dysfunctional relationships with their mothers have likely experienced less happy faces). However, there are many different types of dysfunctional parent-child interactions involving both hostility and withdrawal, so we are unable to disentangle if parent-child dysfunction in the current study is assessing greater anger or sadness in the infant's home environment. Future research should be completed with clinical populations or observational measures to examine how differences in types of dysfunctional parent-infant interactions influence the infant brain. Although the total stress subscale predicting HbR activation during the angry and sad faces conditions seems to go against the novelty hypothesis, because there is significant overlap with negative emotionality in the model this may be reflective of the relationship between negative emotionality and maternal stress.

Our hypothesis that infants with high negative emotionality would be most activated by happy faces was confirmed by multiple regression analyses that found negative emotionality to be a significant predictor of level of HbO activation of all conditions, but strongest during the happy faces condition. This lends more support for the novelty hypothesis (Ravicz et al., 2015; Martinos, Matheson, & de Haan, 2012; de Haan et al., 2004; Field et al., 1998). We also found negative emotionality to be correlated with both HbO and HbR activation during all conditions. The pattern of significant brain activation in response to *all* emotion conditions may be representative of these children being more sensitive and reactive to their environment in general (Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007). Regardless, it is clear that negative emotionality is strongly linked with infant reactivity to emotion face processing.

There were also some unexpected findings, such as opposite hemodynamic responses observed, such that HbO activations were negative and HbR activations were positive, when the reverse is usually found. Although this is not necessarily novel (Quaresima et al., 2005; Hoshi et al., 1994). Future research is needed to understand why this might happen and if it is meaningfully related to brain activity or infant development.

Limitations and future directions

This study has several major limitations including lack of diversity and a small sample size, which limits the generalizability of our findings. Additionally, the equipment used in the study was not specifically designed for infants and, even with modifications, the cords were often heavy on the infants' heads. The cap itself needed to be tight enough on the infant's head so that the source and detector optodes could transmit information about brain activation for the fNIRS machine which may have also been uncomfortable for the infants and increased our termination rate. Ultimately, we wanted to be mindful and aware of the infant experience and erred on terminating the lab session at signs of infant emotional distress.

Conclusions

This study underscored the importance of studying brain activation within the larger context of parent-child dynamics and individual differences in infants' emotional dispositions, as we found these factors were related to brain activation in the mPFC, a ROI found in previous research on emotion regulation (Gee et al., 2013). The development of the infant brain is a reflection of a relational environment and adding to our understanding of how "outside" factors "get under the skin" and result in internal emotional experiences will be crucial in fully understanding the infant brain.

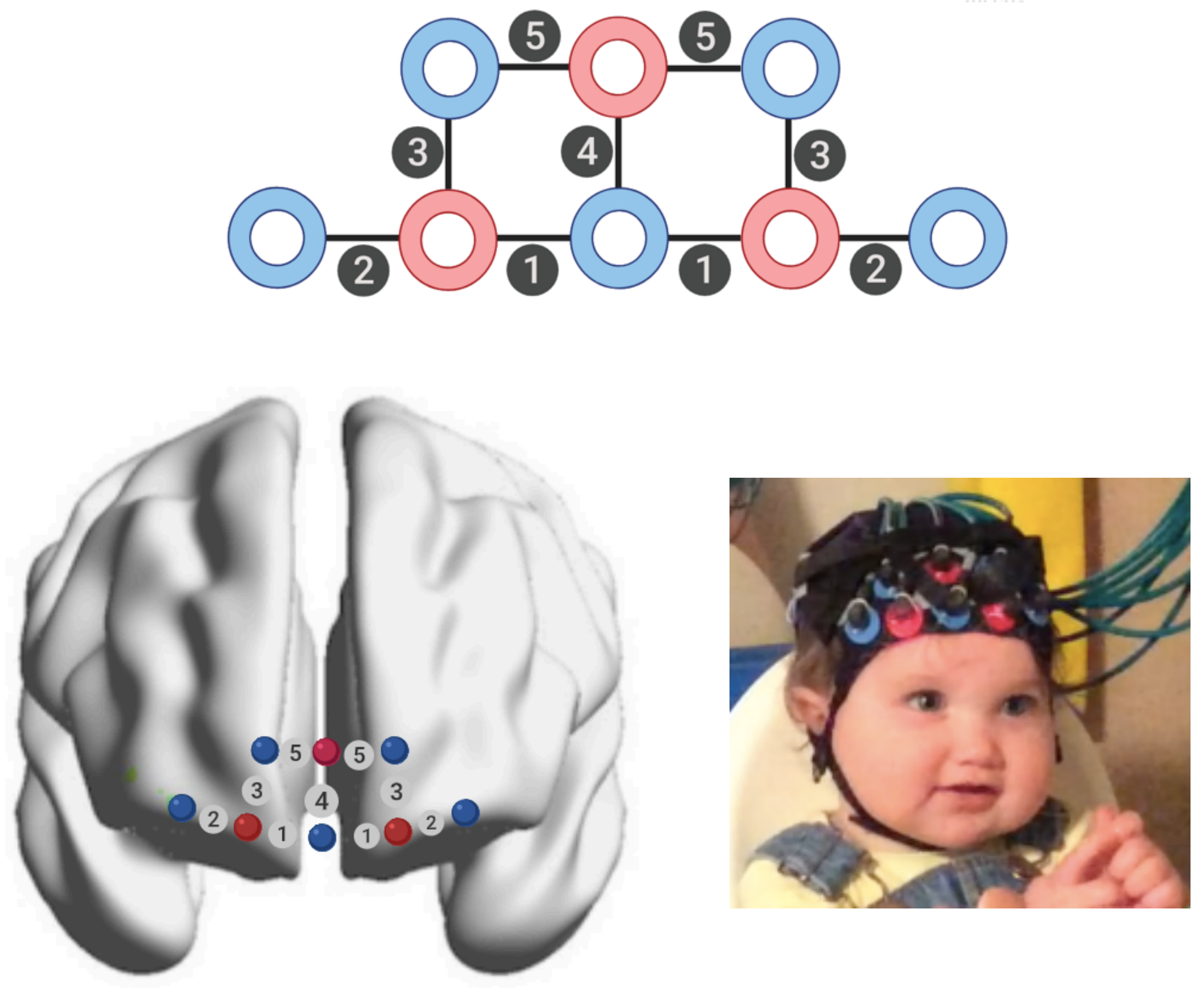

Figure 3.1. Functional NIRS probe configuration, 3D brain template with probe-set overlay. Probe set and channel configurations denote connections between sources and detectors. Red and blue optodes correspond to source and detector placement at a distance of 2.5 cm over an average brain template.

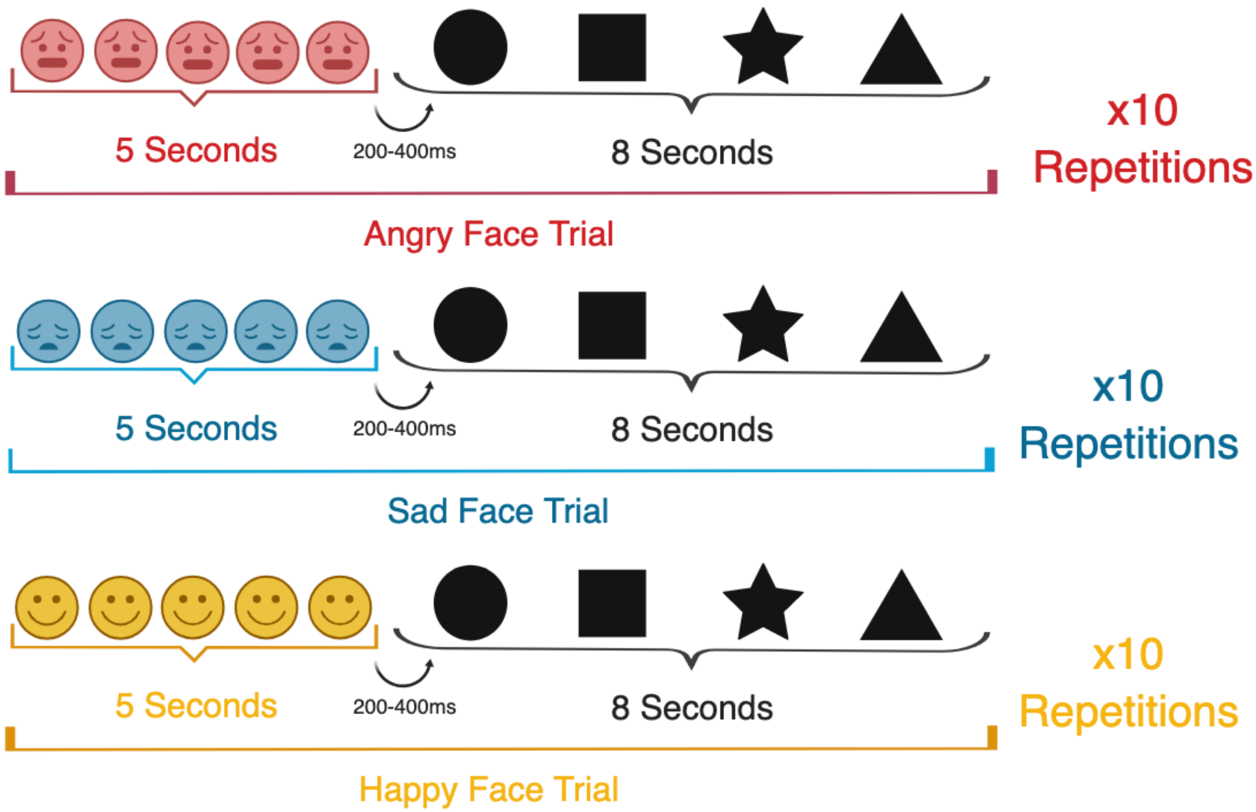

Figure 3.2. Emotion faces task trials.

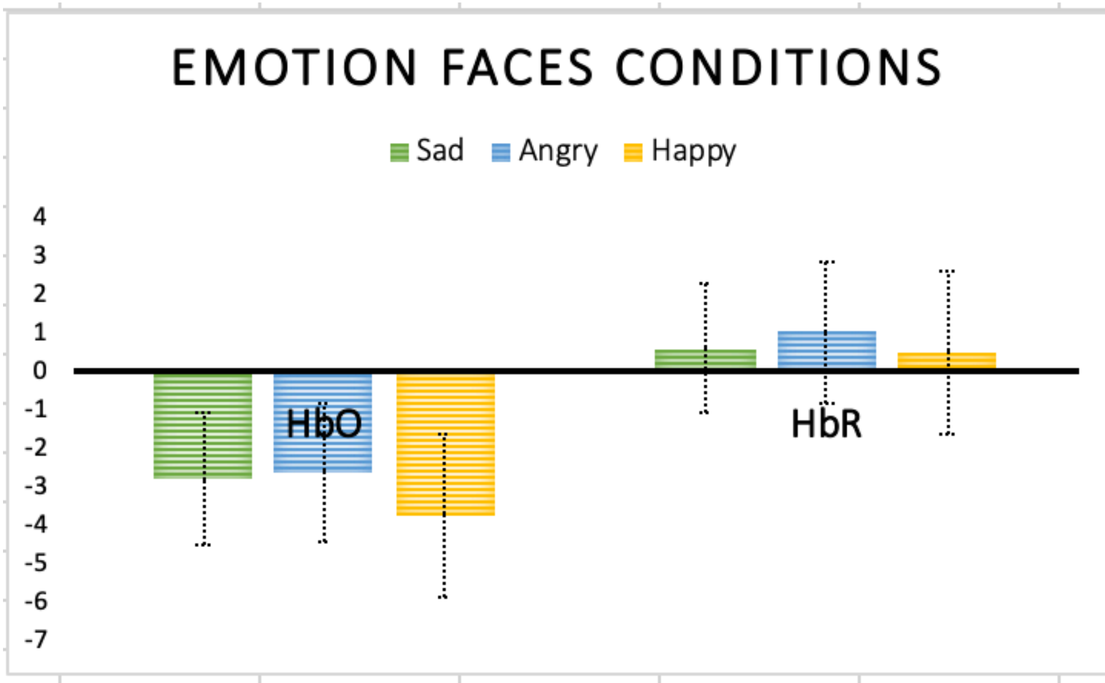

Figure 3.3. Bar graph of total HbO & HbR for each emotion faces condition.

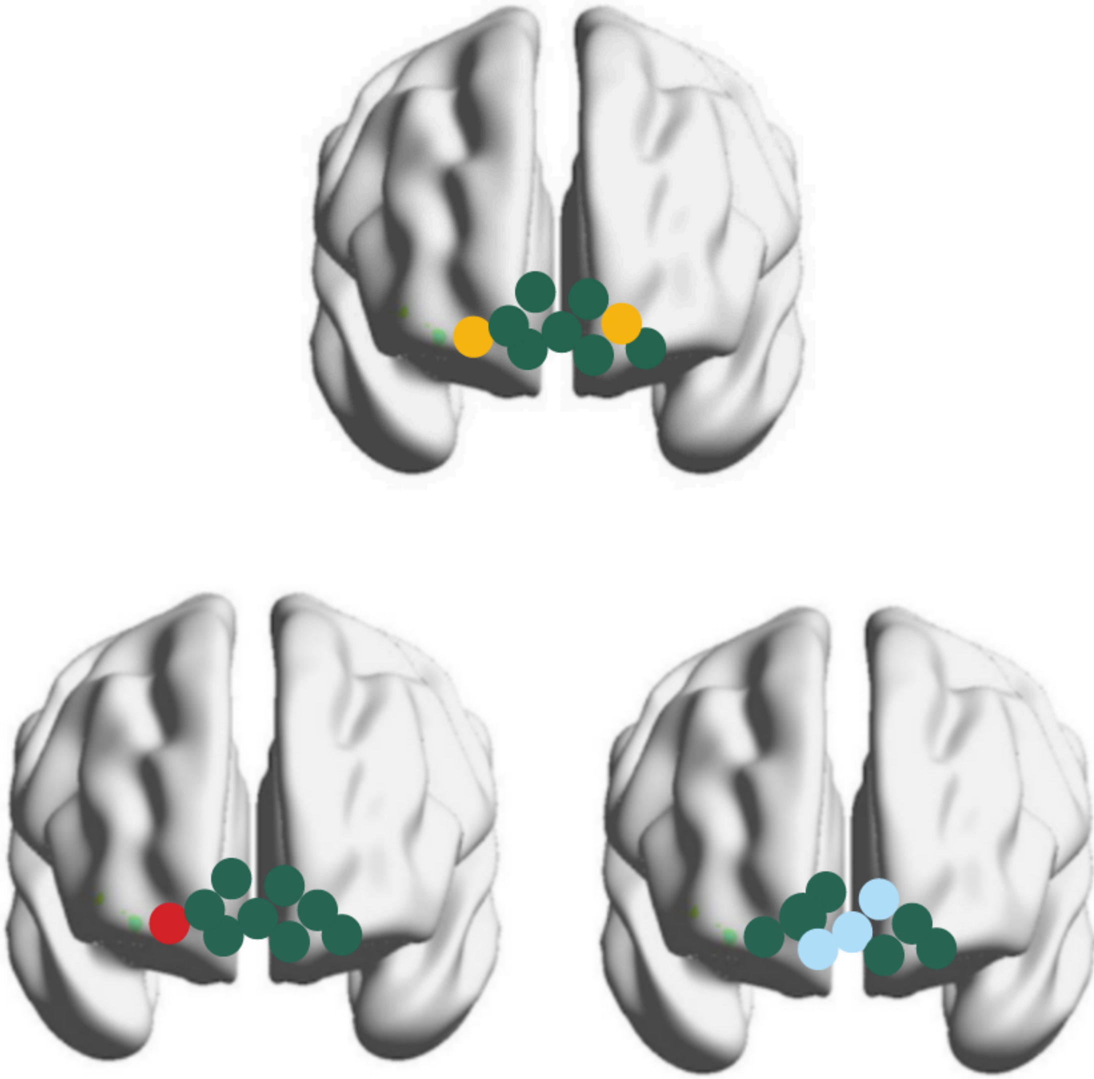

Figure 3.4. 3D brain activity effects for significant HbO channels during the emotion faces task. Yellow = Happy face condition, Red = Angry face condition, Blue = Sad face condition. Green = >.05.

Table 3.1.

Sample Characteristics (N = 16).

	%
Maternal education	
Associate's degree	7%
Vocational degree	7%
Some college	14%
Bachelor's degree	43%
Master's degree	22%
Doctorate	7%
Marital status	
Married	94%
Partnered	6%
Household income	
10,000-30,000	37%
30,000-60,000	6%
60,000-80,000	20.73%
90,000-100,000	25%
> 100,000	19%
Infant gender	56% (male)
Infant Race/Ethnicity	
Black	6%
White	62%
Latinx	13%
Asian	6%
Multiracial	13%

Table 3.2. *Participants' Average Survey Scores.*

Measures	**M**	**SD**
Parenting Stress Index (PSI)		
Defensive Responding	23.60	5.34
Difficult Child	46.80	7.58
Parental Distress	41.50	8.03
Parent-Child Dysfunctional Interaction	54.00	5.83
Total Stress	142.3	17.72
Infant Behavior Questionnaire-Revised (IBQ-R-SF)		
Surgency/Extraversion	5.08	0.64
Negative Emotionality	3.62	0.75
Orienting Regulating	4.92	0.47

Table 3.3. *Pearson Correlations Between Total HbO and HbR per Condition, Infant Temperament, and Maternal Stress.*

Scale	Happy HbO	Happy HbR	Sad HbO	Sad HbR	Angry HbO	Angry HbR	1.	2.	3.	4.	5.	6.	7.
Happy HbO													
Happy HbR	**-.870****												
Sad HbO	**.964****	**-.881****											
Sad HbR	**-.861****	**.979****	**-.856****										
Angry HbO	**.955****	**-.916****	**.980****	**-.890****									
Angry HbR	**-.893****	**.987****	**-.882****	**.989****	**-.907****								
1. Surgency/ Extraversion	-.145	.319	-.223	.246	-.184	.260							
2. Negative Emotionality	**-.582***	**.698****	**-.627***	**.673****	**-.638****	**.663***	**.590***						
3. Orienting/ Regulating	.043	.188	-.028	.167	-.012	.156	.256	-.118					
4. Total Stress	.177	.512	.271	**.697***	.468	**.707***	-.009	-.280	.594				
5. Difficult Child	.231	.435	-.002	.414	.039	.340	.104	-.317	.641	**.828****			
6. Parent-Child Dysfunction	.488	**.680***	.246	.558	.085	.494	-.153	-.368	.651	**.751***	**.840****		
7. Parental Distress	-.268	-.014	.298	.420	**.723***	.555	-.003	.080	-.045	.417	-.114	-.214	

Note. *$p < .05$. **$p < .01$.

Table 3.4. *Multiple Regression Analysis of Infant Temperament and Maternal Stress Predicting Happy, Sad, and Angry Face HbR Activation.*

HbR	**Predictor Variables**	***B***	***SE(B)***	***β***	R^2	***F***
Happy	Parent-Child Dysfunction	17929.34	3609.93	.917	.68	6.03*
	Negative Emotionality	127683.42	36555.85	.645	.91	13.94**
Sad	Total Stress	7982.130	2685.30	.797	.49	6.60*
	Negative Emotionality	86617.51	65034.66	.357	.60	4.56
Angry	Total Stress	5883.515	2062.73	.788	.50	6.98*
	Negative Emotionality	52777.40	49957.27	.292	.58	1.12

Note. $*p < .05$. $**p < .01$.

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CHAPTER 4: General Discussion

The overarching goal of this dissertation was to further an increased understanding of the development of infant emotion processing and early emotion regulation. Sameroff (2009) stated that mental health diagnoses for infants cannot be separated from relationship diagnoses. He wrote that in early development life is a "we-ness" rather than an "I-ness" meaning that the infant experience is so intertwined with that of their caregiver it is difficult, clinically, to view the infant as a separate entity.

We know that the early caregiving relationship has been shown to have implications for a number of significant developmental outcomes, such as mental health, physical heath, and economic outcomes (Ursache, Blair, & Raver, 2012; Curry & Widom, 2010), and yet so much is still unknown about the mind of the infant. A recent article published by Goksan and colleagues (2015) was titled, "fMRI reveals neural activity overlap between adult and infant pain"—the crux of the article being that brain imaging has revealed that infants do, in fact, feel pain in a way similar to adults. The article went on to discuss how historically, because infants cannot self-report pain, and because researchers believed that the infant brain did not process pain at the level of the cortex (Rodkey & Riddell, 2013), there was still controversy about whether infants could feel pain affectively. For instance, although infants in intensive care average 11 procedures a day, 60% of them did not receive any type of painkiller because of this lack of belief in infant pain (Roofthooft et al., 2014).

One might find it shocking that people (some doctors and/or researchers) still believe that infants cannot feel physical pain. These findings, however, put into context how even more difficult it might be for some to grasp that infants can feel *emotional* pain. The recent federal government Family Separation Policy is an example of how a lack of knowledge about infant socioemotional development, and empathy for infants (and children and parents, in general) can, in an instant, lead to severe trauma (Ramos-Olazagasti & Trends, 2018; Teicher, 2018). This dissertation sought to elucidate aspects of the infant emotional experience with the hope that over time, the mental health of infants and children will become more acknowledged and respected.

Research Questions and Theoretical Implications

This dissertation asked several questions about early emotional development. Study one investigated the efficacy of a classic paradigm used in Developmental Psychology, the Face-to-Face Still-Face (FFSF), and its use as a measure of emotion regulation and a potential early indicator of attachment security at the end of the first year. Study two investigated the link between activation of the Medial Prefrontal Cortex (mPFC) and infant emotion face processing to elucidate the influence of infant temperament and maternal stress on how the developing brain processes emotions.

Study 1. For study 1 our main research questions focused on whether we could use person-centered analyses to find individual differences in infant affect during the FFSF. Using latent profile analysis (LPA), we found four classes or groups of infants sharing common patterns of responding to the FFSF, which is similar to other studies utilizing person-centered analyses to uncover different groups of infants based on their responses to the FFSF (Barbosa et al., 2018; Montirosso et al., 2015; Papoušek, 2007; Qu & Leerkes, 2018). These four groups included: a *social-positive oriented* group that remained positive throughout the FFSF, a *classic-*

still-face effect group that became upset during the still-face episode of the FFSF but was able to almost fully recover during the reunion episode, a *distressed-inconsolable group*, that demonstrated predominantly negative affect throughout the paradigm, and a *self-comfort oriented group* that showed positive affect during the still-face episode, and negative affect when interacting with their mother during the free-play and reunion episodes.

After finding these groups, it made sense theoretically to examine if we could find significant predictors of the groups based on maternal behavior, as other research has demonstrated the impact of the caregiving environment on the development of emotion regulation (Schore, 2015; Zeanah, Smyke, Koga, & Carlson, 2005). Also, because the FFSF is a dyadic task, it was expected that the infant and mother will be meaningfully connected. In fact, the earliest article featuring the FFSF positioned it as a way of capturing the mutual regulation processes of the dyad (Tronick et al., 1978). We did not find a strong link between the presentation of infant negative and positive affect during the FFSF and maternal behaviors, and it is not clear why this was the case although several aspects of the current work may be responsible for the lack of findings, including the coding system used, the variables included in the analyses, the timing of the assessments, and the overall question of whether the FFSF truly is a reflection of mutual regulatory processes.

The study was longitudinal in nature so we could assess the stability of our groups over time at 3 and 7 months, and whether they predicted attachment quality at 14 months, two of our other research questions. We did not find stability in class membership at 3 and 7 months, and also did not find a connection between the different profiles at these earlier ages and attachment quality at the end of the year. These results make theoretical sense according to Bowlby's phases of attachment which distinguish between discriminated sociability from 2 to 6 months, a time when infants begin to focus their attachment behaviors toward specific caregivers, and the phase of attachment which begins at 7 months and spans to 24 months (Bowlby, 1969). However, previous studies have found a link between the FFSF and attachment quality (Braungart-Rieker et al., 2014; Mesman et al., 2009).

Study one has major implications for developmental researchers who use the FFSF. First, by calling into question the more normative variable-centered analysis of the FFSF, second, by highlighting the discord of the literature, third, by finding alternative reactions by infants during the FFSF that rival the "classic still-face" response, thought to be the sole pattern representing a securely-developing child. This is not the first time many of these issues have been highlighted. Mesman and colleagues' (2009) meta-analysis of the FFSF literature is a must-read for any researcher planning to utilize the FFSF paradigm and brings to light the lack of standard procedures surrounding this paradigm when it comes to variable such as coding system and age of administration.

Ultimately, we need more research in all these different areas to understand what construct the FFSF is measuring, and how to confidently measure it. I hope that the FFSF will find its true place in the developmental literature, as I believe one reason the FFSF is used so frequently even though there are many problems with it, is because it feels so clinically meaningful when it is conducted and one can see first-hand the diverse responses of infants and parents in the FFSF. Continuing to use the FFSF in research studies without addressing its major issues will not yield meaningful data.

Study 2. Study 2 of this dissertation was smaller in scope, focusing on the activation of the infant brain in response to three different types of emotion faces; happy, sad, and angry. The majority of previous imaging studies using both EEG and fNIRS found evidence for the novelty hypothesis—that infants demonstrate more brain activation in response to the emotion face they have least experienced. Therefore, our hypothesis was also in line with the novelty hypothesis. We extended this research by focusing on the mPFC, thought to be an important structure in emotion processing and regulation of the amygdala, a brain structure that is developing rapidly during the first year of life. We also included surveys of infant temperament and maternal stress in order to attempt to integrate the impact of social context into this study. Theoretically, if the dyadic relationship between mother and child is a significant predictor of emotion regulation (Sameroff, 2009), characteristics of the mother and infant should also influence the development of emotion processing—an important aspect of emotion regulation. Tottenham (2017) links the mPFC with caregiving by referring to the parent as a possible "external social regulator at the time of mPFC maturity", and her empirical work has found this to be true with children younger than ten, providing some empirical justification that this is also the case for infants.

Our results reflected previous research (Ravicz et al., 2015), that temperamentally difficult infants high in negative emotionality demonstrated more brain activation in response to happy faces. We also found a positive association between the Parental Stress Index-Short Form and brain activation during the happy face condition. This suggests that future research should continue to examine infant and maternal characteristics, and how early dyadic interactions influence brain development and activation.

Implications for Social Work Practice and Education

Taken together, these studies highlight the significance of the caregiver-infant relationships in early childhood. In terms of social work practice, the question then becomes, how can we support infant social-emotional development in the absence of a healthy relationship between infant and caregiver? I am not alone in asking this question or believing in the importance of the quality of care an infant receives, and there are high quality interventions that exist in this vein. Increasing our knowledge of the shift from mutual-self regulation and the infant brain (and mind) can only strengthen these interventions. Additionally, because emotion regulation is a multifaceted concept influenced by developmental stage and is measured in a variety of ways throughout the empirical literature, it is difficult to assess efficacy in this area. Because of this, interventions are often assessed solely at the parental level. fNIRS could play a key role in evaluating the effect of interventions on the infant emotional brain.

Ultimately, I want to continue to use brain imaging to understand the development of emotion regulation during infancy and use this methodology to assess intervention efficacy. Observing infant brain activation during dyadic interactions with their caregivers would allow the examination of parent-infant attunement as well as deepen our understanding of the mechanisms involved in the intergenerational transmission of cognitions and behavior. fNIRS could also be used to examine the impact of abuse, neglect, and trauma on the infant brain. I hope to increase our understanding of the internal world of the infant, or on a more basic level convince others that infants *have* an internal world.

Additionally, the concept that infants lack the ability to self-report emotions (Rodkey & Riddell, 2013) dismisses infant cues such as crying or smiling. Understanding and responding appropriately to infant cues is the definition of sensitivity, which we know leads to mental and physical well-being for children (Luby et al., 2013). Therefore, it is important to provide education about infant and child development not only to parents but also helping and medical professionals. Although this dissertation focuses on the impact of mothers on infant development, caregivers do not exist in a vacuum. Bronfenbrenner's ecological model

(Bronfenbrenner, 1978) and Sameroff's transactional model (Sameroff, 2009) emphasize the influence of larger structural inequalities on mental health.

Because social workers provide the majority of mental healthcare in this country (NASW, 2004) it is especially important that we integrate infant mental health and neuroscience understanding into social work education. The concept of infant mental health was originated by social worker Selma Fraiberg (Fitzgerald & Barton, 2000), but has yet to be truly embraced by schools of social work across the country. Infant mental health involves a framework of viewing the *relationship* between parent and infant as the "patient", instead of focusing on either parent or infant. The goal is to improve the infant's mental health outcomes through changing the ways that parent and infant interact. The two main aspects of this modality include understanding how the parent's present and past experiences influence how they view their infant as well as the characteristics of the infant that may play a role in relationship discord (i.e. temperament) (Lieberman, Silverman, & Pawl, 2005). The flexibility of focusing on the relationship also allows room for other caregivers and family members to be involved in treatment. Neuroscience research supports these constructs.

For example, a powerful study by Abraham and colleagues (2014) found that while the brain responses of primary-caregiving mothers and secondary-caregiving fathers demonstrated differences in response to new parenthood, the brains of gay fathers showed a combination of these two effects. This finding validates the need for researchers to move beyond the mother-infant dyad, which not only puts undue pressure on mothers, but does not acknowledge the diversity of families in 2019. Instead, taking a child-centered approach and recognizing the dissimilarities in all types of family structures will lead to more effective interventions. There is also opportunity in the literature to investigate these claims from the perspective of the infant brain, which could provide additional evidence that primary caregivers of *any sort* can scaffold infant brain development. Considering that it was not until 2017 that same-sex adoption became legal in all 50 states, continuing this line of research is very important.

Lastly, this research could aid in providing a more targeted window of early intervention. Study 1 did not find links with attachment at 3 months, which offers additional evidence that earlier in life infants' models of relationships are more malleable and why early intervention is so important. Study 2 offers a glimpse of the neural underpinnings of the mother-infant relationship, and brain development processes, which shows that negative emotionality and parent-child dysfunctional interactions are already influencing the infant brain as early as 6-months-old. This suggests that screening for dysfunctional interactions and negative emotionality early on and offering psychoeducation to these families may be one basic way to aid in early intervention or identify families that may need more support. As a joint doctoral student in Social Work and Developmental Psychology, these interdisciplinary studies strongly underscore the impact of early relationships. However, as a Social Work Practitioner I believe that the power of harmful relationships in early childhood do not have to define an individual's psyche. A greater understanding of infant emotional development can only aid in child (and adult) well-being.

Based on this research, and a neuroscience-informed infant mental health framework, I believe that the most effective interventions focus on supporting caregivers in understanding the needs of their infants and responding to them. For example, Wait, Watch, and Wonder (WWW) is a treatment modality based on modalities of infant mental health. During one WWW session, the parent is instructed to spend half the session playing on the floor with the infant, interacting only when the infant initiates contact and following the infant's lead. This allows the caregiver to observe the infant and gain insight regarding the infant's needs. During this time, the infant is given control over the relationship and environment (to the degree that is safe), which fosters confidence and exploration. The aim is for the parent to be able to comprehend the infant's experience and follow his or her lead (Cohen et al., 1999).

Another approach to helping parents' gain insight into the minds of their infants is the Speaking for Baby Intervention. This intervention focuses on adverse experiences from the past that may be influencing the relationship between parent and infant. During periods of interaction with the infant, parents are instructed to "speak" for the baby, as a way of helping the parent understand the infant's feelings as well as getting in touch with their own negative experiences from the past to separate them from their current caregiving (Carter, Osofsky, & Hann, 1991). Parents often only have the experience of their own caregiving to fall back on when parenting their own children, so this intervention helps them explore their own experience and make more informed decisions about parenting.

Although these interventions utilize different tools, the goal is ultimately the same—to aid parents in viewing their infant as an autonomous being with individualized needs. These therapies help parents recognize the signals their children are giving them and respond to them in a sensitive manner. In essence, teaching parents to recognize and respect the internal world of the infant. As seen in Study 1, infants develop emotion regulation strategies within the first year of life and need both caregiver support and encouragement of their independence to gain these skills. Study 2 demonstrates the importance of parent-infant interaction as applied to basic brain responses and shows why it is important to involve the infant in the intervention—because not all babies are the same. Parents need to be able to understand their infant, specifically, not infants, generally. These interventions could be additive to other types of mental health interventions for adults that are also parents.

In my next phase of research, I hope to build on our knowledge of the infant's internal world by focusing on more naturalistic interactions between parent and child and recruiting more diverse samples including fathers and high-risk infants. Building on this information, I want to create interventions that support parents in understanding their infants. As an assistant professor of Social Work, I will create course content that is inclusive of neuroscience and infant mental health perspectives.

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