Co-regulation and the quality of the relationship during face-to-face interactions in full-term and very low birthweight preterm infant-mother dyads

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ABSTRACT

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Kelly Doiron

Interactions with parents form the basis of infants' social-emotional development. Co-regulation during interactions occurs when partners adjust behaviour based on cues from each other. Research has examined co-regulation in low-risk populations, however co-regulation in the context of dyads' relationships in at-risk populations has yet to be explored. The present study investigated co-regulation and quality of relationships between mothers and their 6-month-old full-term (n = 43) and very low birthweight/preterm (VLBW/preterm; n = 44) infants.

The objectives were to examine: (1) how co-regulation changed following a perturbed interaction, (2) how co-regulation differed between full-term and VLBW/preterm infant-mother dyads, and (3) the association between co-regulation and the quality of the mother-infant relationship.

Mother-infant interactions were coded for time spent in patterns of co-regulation using the *Revised Relational Coding System* (Fogel et al., 2003). Quality of the mother-infant relationship was assessed using the *Emotional Availability Scales* examining maternal and infant dimensions (Biringen et al., 2014; Carter, Little, & Garrity, 1998). Dyads participated in the Still-Face (SF) procedure (Tronick et al., 1978) consisting of two 2-minute face-to-face interactions with a 2-minute period in between where mothers assumed a "still face" and refrained from interacting with their infants. Following the SF period, dyads engaged in more active and disruptive patterns of co-regulation. While full-term dyads engaged in more sequential-symmetrical, VLBW/preterm dyads engaged in more resonant-symmetrical co-regulation. Infant responsiveness, maternal sensitivity, and parental stress were associated with co-regulation. The results highlight the importance of co-regulation and the influence of risk status and relationship quality on co-regulation.

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Co-regulation and the quality of the relationship during face-to-face interactions in full-term and very low birthweight preterm infant-mother dyads

Interactions with parents form the foundations from which infants' social-emotional competence develops. These initial forms of communication allow infants to interpret their worlds, understand social rules, and develop relationships. During exchanges, infants and caregivers are constantly monitoring and changing their behaviour based on interpretations of the others' behavior. Thus, when infants interact with their caregivers, dyads are engaging in co-regulation of their interactions, as each member changes their behaviour based on the input and behavior of their interactive partner. Previous research has supported the benefits of adaptive co-regulative styles in relation to the quality of the parent-infant relationship, while also highlighting the risks associated with maladaptive mother-infant co-regulation (Evans & Porter, 2009). For example, co-regulated interactions where both mother and infant are actively engaged at six months of age have been associated with secure mother-infant attachment styles at one year (Evans & Porter, 2009). However, there is a dearth of research examining patterns of co-regulation and concurrent mother-infant relationship quality. Furthermore, although a wealth of research indicates differences in interaction styles between full-term and very low birthweight (VLBW)/preterm infants (Muller-Nix, Forcada-Guex, Pierrehumbert, Jaunin, Borghini, & Ansermet, 2004; Feldman & Eidelman, 2007; Barnard, Bee, & Hammond, 1984), few studies have gone beyond the examination of discrete behaviours from each partner to examine the dyad as a unit of analysis within the interaction. That is, studies investigating the association between *co-regulation* and mother-infant relationship quality in VLBW/preterm infants are sparse. Given the difficulties with regulation that have been reported in VLBW/preterm infants, such as increased negative affectivity and difficulties in soothing (Jahromi, Putnam, & Stifter, 2004), it is imperative to examine how both members of the dyad contribute to regulation in VLBW/preterm infants. Thus, these gaps in the literature were addressed in the current study.

Co-Regulation Between Mothers and their Infants

Research has demonstrated that the development of appropriate expectations of infants in social situations is facilitated by warm caregiving that is sensitive to infants' cues and results in appropriate responses to the needs of the infants (Bronson, 2000). During co-regulation the goal of the dyad is to achieve a coordinated state of interaction (Fogel, 1993). To do so, caregivers and infants must have appropriate expectations of the actions of their partners. Given the

important role of expectations in successful interactions, further research is needed to examine sensitive caregiving as a facilitator of adaptive co-regulation, particularly in at-risk populations such as VLBW/preterm infants.

Historically, infants have been viewed as passive receptors of social stimuli, however current perspectives describe even young infants as actively interpreting their worlds, interacting with others, and in particular, regulating emotions and behaviours (Fogel, 2010). For example, before three months of age, infants show early signs of regulating arousal by diverting their gaze from over-arousing stimuli and using sucking as a way to self-soothe (Bronson, 2000). Caregivers offer additional regulation by addressing infants' physiological needs and assisting in decreasing arousal through avenues such as touch (Moreno, Posada, & Goldyn, 2006; Jean & Stack, 2009; Jean & Stack, 2012; Stack, 2010). Although both caregiver and infant contribute independently to regulation of arousal, the mother-infant dyad can also be examined as a unit of analysis in the regulation of their interaction; that is, in the co-regulation of interactions. This approach of investigating co-regulation of the dyad as a whole is embedded in dynamic systems theory, which posits that the behaviour of both mother and infant are constantly impacting the manner in which they interact (Fogel & Garvey, 2007). Furthermore, a transactional influence occurs whereby mothers and infants influence the behaviours of each other under the influence of their surrounding environment (Sameroff, 2009).

Caregivers and infants are always engaging in co-regulation during their interactions; however, the nature of that co-regulation can vary greatly. Hsu and Fogel (2003) identified three common patterns that occur during mother-infant interactions: symmetrical, asymmetrical, and unilateral. During symmetrical co-regulation, both members of the dyad are actively engaged and contributing to the interaction, whereas in asymmetrical patterns of co-regulation both members are engaged, but only one member is making active contributions. In contrast, unilateral co-regulation consists of an interaction where one member of the dyad is engaged (and may or may not be active), while the partner is unengaged. In addition, both members of the dyad may be unengaged or one member may interrupt or misinterpret the cues of the partner, which may potentially result in frustration as miscommunication ensues (Bronson, 2000). Past research has suggested a developmental change in the predominant form of co-regulation used over time, with infants becoming increasingly engaged and active in interactions over their first year of life (Evans & Porter, 2009). These results indicate that in healthy full-term dyads a shift occurs in

infants' co-regulative abilities as they develop expectations about social interchanges and become more active members within the interaction between six and twelve months of age.

Studying full-term infants provides a great deal of insight into the normative development of co-regulation. However, it is also important to consider the development of co-regulation in vulnerable groups, such as VLBW/preterm infants, in order to shed light on potentially important developmental differences in their regulatory process. Indeed, given that previous research has illustrated the benefits of full-term infants' active engagement in interactions with their mothers for both social and cognitive development (Evans & Porter, 2009), it is crucial to examine co-regulation in both low and high risk populations, such as VLBW/preterm dyads, as a source of fostering healthy relationships, but also as an avenue to examine paths for increased risk.

An abundance of studies have demonstrated the regulatory and interactive differences that exist between full-term and preterm infants. Results from previous research have characterized preterm infants as being more excitable and irritable, as well as less alert than infants born full-term (Als, Duffy, & McAnulty, 1988; Hsu & Jeng, 2008). Furthermore, preterm infants have shown greater difficulty in regulating their own emotional states and thus, tend to be more difficult to soothe than full-term infants (Als, Duffy, & McAnulty, 1988; Hsu & Jeng, 2008). Given the transactional nature of mother-infant interactions, it is not surprising that maternal behaviours also differ among mothers of preterm infants compared to full-term dyads. Feldman and Eidelman (2007) found that mothers of preterm infants displayed higher rates of maternal depression and engaged in fewer mother-infant bonding behaviours than their full-term counterparts. Results from other research have found that mothers tend to engage in more intrusive behaviours towards and be less responsive to their preterm infants (Muller-Nix et al., 2004).

Strained interactions in preterm infant-mother dyads who were also born very low birth weight (VLBW/preterm) may be further exacerbated by difficult environmental circumstances surrounding the specialized medical care required for VLBW/preterm infants. In a qualitative meta-analysis conducted by Aagaard and Hall (2008), mothers described their experiences of having a preterm infant in the neonatal intensive care unit (NICU) as feeling like a stranger to their infant and feeling upset at not getting to know their infant, as well as distress about the infant's condition. Mothers also described the NICU environment as overwhelming and inducing feelings of anxiety (Aargard & Hall, 2008). Furthermore, Montirosso, Del Prete, Bellù, Tronick,

and Borgatti (2012) found that higher levels of developmental care (i.e., environments that minimize infant stress) were associated with greater regulation and less excitability and stress among very preterm infants. In addition, results from studies on maternal contributions to co-regulation have suggested an association between co-regulation and infant self-regulatory behaviours. In their examination of maternal touch, Jean and Stack (2012), found that full-term and VLBW/preterm infants' self-regulation was positively associated with maternal touch, suggesting that co-regulation facilitates infants' abilities to regulate their own arousal. In addition, VLBW/preterm infants have been shown to benefit both physiologically and cognitively from physiological forms of co-regulation such as skin-to-skin contact later in childhood, particularly in their abilities to handle stress (Feldman, Rosenthal, & Eidelman, 2014). Maternal benefits were also observed, whereby mother-infant contact lead to less maternal anxiety (Feldman, Rosenthal, & Eidelman, 2014).

The Quality of the Mother-Infant Relationship

The manner of co-regulation occurring in dyads also has implications for the caregiver-infant relationship. Greater time spent in symmetrical co-regulation at six-months of age predicted secure attachment at twelve months and greater cognitive and psychomotor development at nine months (Evans & Porter, 2009). In contrast, infants' lack of engagement and contribution to the interaction (unilateral) predicted insecure attachment and was negatively associated with cognitive development (Evans & Porter, 2009). Given that co-regulation develops within the context of the infant-caregiver relationship, but also influences that relationship, a transactional approach that incorporates both context and the relationship would provide a deeper understanding of the socio-emotional development of infants and how co-regulation and the nature of the infant-caregiver relationship may interact differently in VLBW/preterm infants.

The nature of the mother-infant relationship evolves through contributions from both members of the dyad (Fogel, 1993). Studies have suggested that warm, sensitive caregiving paired with a responsive infant fosters appropriate social expectations through contingent behaviours (Bronson, 2000). Maternal sensitivity involves congruency of emotional expressions and interpreting emotional cues of the child appropriately (Biringen, Derscheid, Vliegen, Closson, & Easterbrooks, 2014; Ainsworth, Blehar, Waters, & Wall, 1978; Smith & Pederson, 1988; Perry, Mackler; Calkins, & Keane, 2014). In contrast, infants' development of

expectations is hindered when their cues are misinterpreted or ignored (Bronson, 2000). Thus, the manner in which caregivers interpret and act upon their infants' efforts at communication, particularly through their emotions, has implications for both co-regulation and their developing relationships. Furthermore, research has shown that securely attached infants tend to have sensitive and responsive mothers (Ainsworth et al., 1978; Beijersbergen, Juffer, Bakermans-Kranenburg, & van IJzendoorn, 2012; Biringen et al., 2014; de Wolff & van IJzendoorn, 1997; Jin, Jacobvitz, Hazen, & Jung, 2012). However, the nature of parenting and its efficacy is also impacted by infants' contributions (Sameroff, 2009). For example, a mother's hostility towards her infant may be due in part to the infant's difficult temperament (which may in turn be exacerbated by maternal hostility). Results from a study by Jahromi, Putnam, and Stifter (2004) supported this notion in that maternal soothing behaviours were only effective when infant arousal was at a moderate level. In situations where the infant was more upset, mothers showed greater difficulty in consoling their infants (Jahromi, Putnam, & Stifter, 2004). Previous research has supported the integral role of maternal sensitivity and infant responsiveness in infant development and in fostering future positive relationships by enhancing social understanding (Moreno, Klute, & Robinson, 2008; Licata, Paulus, Thoermer, Kristem, Woodward, & Sodian, 2013). Furthermore, Lehman, Steier, Guidash, and Wanna (2002) demonstrated that mothers who showed higher sensitivity had children who were more obedient to their mothers' requests, illustrating the bi-directional nature of parent-child relationships. Thus, mothers showing higher sensitivity may result in both members of the dyad adhering to cues of the other, leading them to engage in more adaptive forms of co-regulation.

While contributions from each member of the dyad are certainly important, contextual variables in the proximal environment of the dyad cannot be ignored. Low socioeconomic status along with low social support and higher stress may exacerbate both maternal hostility and the infant's difficult temperament. Their patterns of interaction and parenting styles might be maladaptive, but the root of that problem may be embedded within factors that cannot be accounted for in isolation. Thus, a dyadic approach that accounts for both maternal and infant factors (acknowledging that both can be active in their interactions), as well as the larger environmental context allows for a deeper examination of the transactions taking place (Kuczynski & Parkin, 2009; Serbin, Stack, Kingdon, Mantis, & Enns, 2011; Stack, Serbin, Girouard, Enns, Bentley, Ledingham, & Schwartzman, 2012). In support of the influence of

environmental context on mother-child relationships, research by Stack et al. (2012) found that better mother-child relationship quality was predicted by lower levels of stress, greater social support, and better home environments. In at-risk populations, such as infants who are born VLBW/preterm, the surrounding environment may be characterized by a great deal of stress, as has been illustrated by Aagard and Hall (2008). Furthermore, research has indicated that caregivers tend to be less sensitive and more controlling of their VLBW/preterm infants (Muller-Nix et al., 2004). These difficult relationships may lead to later problems including internalizing and externalizing behaviour and problematic peer interactions, as demonstrated by Treyvaud, Doyle, Lee, Roberts, Lim, Inder, and Anderson (2012) in their longitudinal study of premature infants. It is thus imperative to consider the mother-infant relationships of VLBW/preterm infants (and the environments within which they are being raised) who may be at an increased risk for both dysregulation and problematic social-emotional development.

Measures and Methods in Examining Relationship and Co-regulation Processes

Along similar lines, when studying the infant-mother relationship and co-regulation during infancy, the methods used to study these processes give rise to different opportunities. Interaction contexts that have generally been used to examine co-regulation and the caregiver-infant relationship have traditionally been free play paradigms because of the naturalistic setting this method offers (Evans & Porter, 2009; Aureli & Presaghi, 2010; Hsu & Fogel, 2003). However, free play procedures fail to provide information on how dyads overcome a challenge, which is when the need for co-regulation may arise and the impact of the quality of parenting can be observed. An alternative way to examine these dimensions is to use Tronick, Als, Adamson, Wise, and Brazelton's (1978) still-face (SF) procedure. During the SF procedure, mothers engage in a series of three face-to-face interactions with their infants. Following the first naturally interactive period, dyads enter into the SF period where mothers assume a neutral expression and refrain from talking or touching their infants. This unusual experience violates social rules of contingency and exchange, and essentially renders the mother emotionally unavailable (Tronick et al., 1978). Furthermore, due to mothers' unavailability, infants are required to regulate their own arousal (Weinberg & Tronick, 1994). The procedure ends with a reunion period where mothers again interact with their infants as they normally would, offering insight into how dyads recover from a challenging situation. Previous research has found increases in negative affectivity, and decreases in smiling during and after the SF period

(Adamson & Frick, 2003; Kisilevsky et al., 1998; Toda & Fogel, 1993; Weinberg & Tronick, 1996; Yoo & Reeb-Sutherland, 2013). Furthermore, premature infants tend to require more time to recover from the SF and display higher reactivity than their full-term counterparts (Hsu & Jeng, 2008). Taken together, the SF provides the unique opportunity to examine changes in co-regulation as a function of the quality of the infant-caregiver relationship arising from a social challenge.

Beyond the interactive context, prior research has tended to focus on discrete measures of co-regulation by examining the infant and mother in isolation, without accounting for the dyad itself as an entity to be examined. By focusing only on maternal contributions to co-regulation, some studies have failed to account for transactional influences of the infant on the mother. The converse has also been true, where a focus on infants' regulatory abilities does not fully account for maternal contributions. Furthermore, there is a paucity of studies using a dyadic approach to compare fullterm to VLBW/preterm infants' co-regulative patterns.

The Present Study

The present study was designed to address these limitations by adopting a dynamic systems (Fogel & Thelen, 1987; Fogel, 1993) and transactional (Sameroff, 2009) approach to the study of mother-infant co-regulation manifested in the *Revised Relational Coding System* (Fogel, de Koeyer, Secrist, Sipherd, Hafen, & Fricke, 2003) using the SF paradigm. There were three objectives. The first objective was to determine changes in proportion of time spent in each pattern of co-regulation from the normal to reunion periods. In terms of overall use of co-regulation, it was predicted that infants would engage primarily in unilateral patterns, as has been demonstrated in previous studies of infants at this age (Hsu & Fogel, 2003; Aureli & Presaghi, 2010). However, it was also hypothesized that both groups would spend a greater proportion of time in symmetrical co-regulation following the SF period. The SF may confuse and thus arouse infants, leading them to seek out and be more willing to engage in active co-regulation following that perturbation. It was also predicted that there would be an increase in disruptive co-regulation. Mothers may not be able to read or address the infant's needs immediately and this may give rise to an already aroused state that upsets the infant. Conversely, dyads were predicted to spend a greater proportion of time in unilateral co-regulation during the initial normal period because there is no induced stressor, pushing the infant to co-regulate.

In the second objective, differences in types of co-regulation employed between full-term and VLBW/preterm dyads were observed. VLBW/preterm infants were expected to spend greater proportions of time in disruptive communication, as they may have greater difficulty addressing their high arousal and thus be more difficult for mothers to soothe than full-terms. Furthermore, it was hypothesized that VLBW/preterm infants would spend less time in symmetrical patterns of co-regulation than full-term infants. Given that VLBW/preterm infants' communication skills were anticipated to be behind that of the full-term infants, it was expected that forms of co-regulation that draw heavily on social rules would be less frequent in VLBW/preterm infants. VLBW/preterm infants were also predicted to spend greater amounts of time in unilateral patterns of co-regulation, as these patterns involve infant behaviours similar to those seen in the regulative strategies of infants younger than three months (Evans & Porter, 2009).

The third objective was to determine the relation between patterns of co-regulation, quality of the parent-infant relationship, and parental stress. It was hypothesized that in both groups higher maternal sensitivity (as measured by the Emotional Availability scales; Biringen et al., 2014) would be associated with more symmetrical, but less asymmetrical communication. In addition, symmetrical co-regulation was expected to be associated with child responsiveness. Unilateral co-regulation and disruptive communication were hypothesized to be associated with maternal hostility (whereby, the infant would be required to either self-regulate or become frustrated with miscommunication) and less infant responsiveness. However, maternal hostility was predicted to be a low frequency behaviour given the low-risk nature of the sample. Finally, parenting stress was predicted to be associated with disruptive co-regulation, when the infant may be more difficult to soothe.

Method

Participants

The current sample consisted of 87 mother-infant dyads (43 full-term) that were taking part in a larger longitudinal study. The present study focuses on the dyads when the infants were 6 months of age. The sample included two groups: infants who were born full-term and those who were born very low birth weight (VLBW)/preterm (see Table 1 for medical and demographic information). Both groups were recruited from the same large teaching hospital in

Montreal, Canada to ensure similar demographic backgrounds (see Table 1). Furthermore, dyads were matched for infant age, sex, and maternal education (within 5 years).

Full-term infants. Forty-eight mother-infant dyads with infants who were born healthy and to full-term were recruited using birth records from a teaching hospital in the Montreal, Quebec area. Mothers voluntarily participated after receiving a letter outlining the study and being contacted by telephone. Infants were healthy, born full-term (between 37-41 weeks gestation) and had a birth weight of more than 2750 grams (6 pounds, 1 ounce). Five mother-infant dyads were excluded from the current study for the following reasons: mothers not following instructions (n = 2), taking a break between the SF and reunion periods (n = 2), and excessive infant fussiness (n = 1). The final sample included 43 full-term mother-infant dyads (21 males, 22 females). The mean age of mothers was 30.33 years (SD = 5.16) and mean age of infants was 5.43 months (SD = .25).

Very low birth weight/preterm infants. Infants who were born VLBW/preterm were recruited from the same teaching hospital as the full-term sample in collaboration with the chief neonatologist and the VLBW follow-up clinic. During their 3-4 week clinic visit VLBW/preterm infants were screened for medical issues by the nurse in charge of the follow-up clinic. Those who met the inclusion criteria (i.e., were healthy and living with their biological mothers and fit the gestation and weight criteria for VLBW infants as detailed below) were given a letter describing the study and later contacted by telephone to voluntarily participate. Infants who were experiencing serious medical issues, or mothers who were at an increased risk for psychosocial problems, were excluded from the study (see Table 2 for detailed inclusion and exclusion criteria). The full sample included 63 mothers that had healthy VLBW/preterm infants who were born between 26-32 weeks gestation and weighed between 800-1500 grams (1 pound, 12 ounces to 3 pounds, 5 ounces). Infant age was corrected for prematurity by subtracting the number of weeks the infant was premature from their postnatal age. Using corrected ages of the VLBW/preterm infants allowed a fair comparison to the full-term group. Nineteen mother-infant dyads were excluded from the study for the following reasons: mothers not following instructions (n = 9), experimenter error in the procedure (n = 6), and excessive infant fussiness during the SF (n = 4). The final sample included 44 VLBW/preterm mother-infant dyads (20 male, 24 female). The mean age of mothers was 32.34 years (SD = 6.00) and the corrected mean age of infants was 5.76 months (SD = 5.16).

Apparatus

Mothers and infants were visited by experimenters in their homes. Their interactions were recorded in a well-lit room with minimal distractions using a Sony video camera. Infants were placed in a car seat that was secure on a table facing their mothers. Infants' and mothers' faces were at eye-level and approximately 70 cm apart. A mirror was positioned to the side and slightly behind the infant to capture the mother's facial expressions. The video camera was placed on a tripod and positioned to face the infant and capture the reflected image of the mother in the mirror. A stopwatch was used to time the periods of the SF procedure. The video records were later digitized for coding purposes. Coding of the interactions was completed in the research laboratory using Mangold INTERACT 9.0 software, which allows for live second-by-second qualitative and quantitative analysis of multimedia data. Following coding, total durations of time in seconds for each portion of the video record (i.e., for each period of the SF procedure), were later divided by the total number of seconds within the period to yield proportions of time spent in each pattern of co-regulation as a function of period.

Procedure

After being provided with a description of the study and procedure, mothers read and signed a consent form. Following the setup of the camera and participants, mother-infant dyads engaged in Tronick et al.'s (1978) still-face (SF) procedure. The SF procedure consists of three 2-minute periods of mother-infant face-to-face interaction. In the first Normal period, the mother is instructed to interact with her infant as she normally would for 2 minutes. Following the normal period is the Still-Face period where mothers are asked to retain a neutral expression and refrain from talking or touching their infants (i.e., mothers are emotionally unavailable and considered to be violating social norms of interaction) for 2 minutes. Dyads then enter into the Reunion Normal period where mothers are again asked to interact with their infants as they normally would for 2 minutes. The time in between each period lasted 20-30 seconds and during this interval the experimenter provided instructions for the next period. Each period was conducted in the absence of toys and pacifiers. Mothers were reminded that they were free to stop the procedure at any time. Furthermore, if the infant became upset for more than 20 seconds, the procedure was stopped until the infant could be soothed and settled. The procedure would then be re-initiated if the mother was comfortable to do so. Only one infant became upset such that the procedure had to be re-commenced. Once all data were collected, mothers were

thanked for their participation and presented with an "Infant Scientist Award" in appreciation for their participation.

Questionnaire Measures

Demographic Information Questionnaire. The demographic information questionnaire (DIQ) was completed by mothers in order to collect socio-demographic information, including maternal level of education and infant health. Previous researchers have used this measure effectively and reliably to collect participant demographic information (e.g., Mantis, Stack, Ng, Serbin, & Schwartzman, 2014; De Genna, Stack, Serbin, Ledingham, & Schwartzman, 2006).

Parenting Stress Index. Mothers were also asked to complete the *Parenting Stress Index* (PSI; Abidin, 1995), which examines psychological distress brought on by the stresses of parenting and measures stress as a parent-child system. The PSI is a self-report measure using a five-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). The current study used the short-form of the PSI, which contains 36 items that load onto three subscales (12 items each): parental distress (distress related to one's role as a parent), parent-child dysfunctional interaction (parent perceptions of the child not meeting expectations and lacking reinforcement as a parent), and difficult child (difficult to manage behavioural characteristics of the child). The three subscales load onto the measure of total stress, which quantifies the overall parenting stress of an individual (Abidin, 1995). The total stress index was the focus for the present study where higher scores indicate greater parenting distress. Reliability of the PSI was calculated from a normative sample and was shown to be excellent with alphas for all subscales calculated to be at or above .80. Furthermore, in normative samples the PSI has shown exceptionally high validity (Abidin, 1995).

Observational Measures

Co-regulation. Type of co-regulation was the primary measure and served as the dependent measure for the present study. Time spent in each form of co-regulation was calculated as a percent duration for each participant in the normal and reunion periods of the SF procedure.

Co-regulation was observationally coded using Fogel et al.'s (2003) *Revised Relational Coding System* (RRCS). This measure examines the synchrony of mother-infant interactions based on the behaviour that both mother and infant are exhibiting towards each other. It requires observing the dyad as a whole (i.e., examining both the mother and the infant) and uses cues

from vocalizations, touch, gaze, affect, and general body language to determine what pattern of co-regulation the dyad is engaging in during that time. Categorization is largely based on how one partner of the dyad responds to cues from the other partner. In order to be coded in a given category, the dyad must have engaged in that form of co-regulation for a minimum duration of 2 seconds. The entire 2-minute period for each of the two normal periods was coded for co-regulation. The RRCS contains 6 overarching types of co-regulation: symmetrical, asymmetrical, unilateral, disruption, unengaged, and no code. There are also sub-codes within symmetrical (sequential and resonant), asymmetrical (demonstrating and expecting), and unilateral (following, initiating, and demanding).

During symmetrical and asymmetrical co-regulation both members of the dyad are engaged with each other or a mutual point of interest. However, both members are active in the interaction when symmetrical, and only one member is active when asymmetrical. In unilateral forms of co-regulation one member of the dyad is actively trying to engage the other member who is not currently engaged. Disruptive co-regulation occurs when one member of the dyad is not adhering to, or understanding the cues of the other member (e.g., an infant crying and the mother not adjusting her behaviour accordingly). When neither member of the dyad is engaged, they are coded as unengaged, and "no code" is reserved for activities not specified in the RRCS manual. Table 3 provides brief operational definitions for each code and sub-code. In the current study, unengaged and no code categories were excluded from analysis due to extremely low frequency (fewer than 1% of the interactions). Furthermore, due to the nature of the interaction, only the overarching asymmetrical code was used in the analyses. Further, asymmetrical demonstrating requires a third object of reference within the dyad, which was rarely available, as toys were excluded from the interaction.

A second coder was trained on the RRCS and coded one third of the sample to establish reliability with the primary coder. The second coder was blind to the hypotheses of the study. A kappa coefficient was calculated for type of co-regulation and the overall kappa collapsed across each type of co-regulation was .80. Table 3 provides kappa and intra-class coefficients for each individual category of co-regulation.

Emotional Availability. To examine the quality of the mother-infant relationship, an adaptation of the *Emotional Availability Scales* (EA scales; Biringen, Robinson, & Emde, 1993; Biringen, Robinson, & Emde, 1998) for infants (Carter, Little, & Garrity, 1998) was used to code

mother and child behavior during the interaction periods. This relational measure is composed of four dimensions (maternal sensitivity, hostility, structuring, and child responsiveness) at this age that assess both the mother and child. Maternal sensitivity refers to mother's assistance of the infant's physiological and emotional arousal as needed. Maternal structuring refers to the mother's boundary setting and structuring of the interaction. Maternal hostility refers to the level of overt and covert hostility displayed by mothers during interactions. Infant responsiveness refers to the infant's active engagement and positive response to interactions with the mother. The EA scales have been used to examine the quality of the mother-infant relationship, particularly in the regulation of their interactions (e.g., Biringen et al., 2014; Din, Riddell, & Gordner, 2009; Garvin, Tarullo, Van Ryzin, & Gunnar, 2012; Kaplan, Evans, & Monk, 2008; Mantis et al., 2014; Stack et al., 2012). A research associate who was trained on the scales coded this measure and thirty percent of the sample was double-coded by a second trained coder. Reliability was determined to be satisfactory using intraclass correlation coefficients for each EA scale (r = 0.82-0.99). Previous studies have shown the EA scales to be both reliable and valid measures of mother-child interactions (e.g., Bornstein, Suwalsky, & Breakstone, 2012; Biringen et al., 2014; Stack et al., 2012).

Results

Data were screened for integrity and to ensure that the data met the assumptions of repeated measures ANOVAs and regression analyses. Descriptive statistics were conducted to determine the normality of the distribution for each category of co-regulation using kurtosis and skew. In addition, percent durations of each category for each participant were converted into *z*-scores to identify outliers. Kline (2009) suggests converting outliers (scores greater than 3 *SD* from the mean) to the next most extreme score within 3 *SD*. After converting outliers to the next most extreme scores, both kurtosis and skew were brought within an adequate range for each category of co-regulation, thus making the distribution normal. Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS, version 18.0). Sphericity cannot be assumed for the ANOVA findings since Mauchly's test of sphericity was statistically significant. Therefore, the Greenhouse-Geisser correction was used for all findings, as suggested by Kline (personal communication, 2013).

Objectives 1 and 2: Comparison of co-regulation across periods and between full-term and VLBW/preterm infants

To test for the impact of period (normal and reunion) and group (full-term and VLBW/preterm) on the percent duration of patterns of co-regulation, a 2 x 2 x 7 mixed analysis of variance (ANOVA) was conducted. The repeated variables were period and patterns of co-regulation, and the between variable was group. Percent duration of each pattern of co-regulation served as the dependent variable. Significant main effects and interactions were followed-up using Bonferroni-corrected simple effects analysis.

A statistically significant main effect of co-regulation was revealed, F (4.03, 342.41) = 76.27, η_p^2 = 0.47, $p < .001$. Bonferroni-corrected simple effects indicated that, collapsed across the two interaction periods, dyads were most likely to engage in asymmetrical (M = 38.40% duration) patterns of co-regulation, followed by symmetrical-sequential (M = 18.50), symmetrical-resonant (M = 14.74), unilateral-initiating (M = 12.42), unilateral-demanding (M = 11.92), disruption (M = 3.11), and unilateral following (M = 1.32). The means and standard deviations for each pattern of co-regulation, as a function of group and period, are provided in Table 4.

Addressing objective 1, a statistically significant interaction between period and co-regulation was found, F (4.48, 381.06) = 5.48, η_p^2 = 0.06, $p < .001$, suggesting that the percent duration that mother-infant dyads spent in each pattern of co-regulation differed between the two interaction periods (i.e., normal or reunion). Comparing co-regulation between interaction periods, it was found that dyads engaged in significantly more symmetrical-resonant patterns of co-regulation during the reunion period (M = 16.33, SD = 1.68) than in the initial normal period (M = 13.15, SD = 1.60; $p < .001$). Dyads also engaged in significantly more unilateral-initiating patterns of co-regulation during the initial normal period (M = 15.93, SD = 1.77) than in the reunion period (M = 8.92, SD = 1.15; $p < .001$). Finally, dyads engaged in significantly more disruption during the reunion (M = 4.64, SD = 1.11) than in the initial interaction period (M = 3.71, SD = 0.97; $p < .05$). In addition, trends were observed whereby dyads engaged in more symmetrical-sequential patterns of co-regulation during the reunion period than in the initial normal period (mean difference = 2.61, $S.E.$ = 1.40, p = .07) and more unilateral demanding co-regulation in the initial normal period than in the reunion (mean difference = 3.30, $S.E.$ = 1.79, p = .07). Figure 1 illustrates the mean proportion of time spent in each pattern of co-regulation for each interaction period.

Addressing objective 2, a statistically significant interaction between group and co-regulation was found, F (4.01, 342.41) = 40.625, η_p^2 = 0.32, $p < .001$, suggesting that the percent duration of time that mother-infant dyads spent in each pattern of co-regulation differed based on the infant's birth status (i.e., full-term or VLBW/preterm). Comparing co-regulation between groups, mothers and their full-term infants engaged in significantly more symmetrical-sequential patterns of co-regulation (M = 35.27, SD = 2.30) than did mothers and their VLBW/preterm infants (M = 1.74, SD = 2.27; $p < .001$). In contrast, mothers and their VLBW/preterm infants engaged in significantly more symmetrical-resonant patterns of co-regulation (M = 28.56, SD = 2.03) than mothers and their full-term infants (M = 0.92, SD = 2.05; $p < .001$). Figure 2 illustrates the mean proportion of time spent in each pattern of co-regulation for each group.

Objective 3: Patterns of co-regulation and their association with emotional availability and parenting stress across period and infant birth status

To examine the association between patterns of co-regulation and emotional availability in the mother-infant relationship each dimension of the EA scales (i.e., maternal sensitivity, structuring, hostility, and child responsiveness) was regressed on proportion of time spent in each pattern of co-regulation. All hierarchical regressions that follow were conducted separately for each interaction period (normal and reunion) and group (full-term and VLBW/preterm). Each hierarchical regression contained two steps. The total stress measure of the PSI was entered in the first step, and maternal sensitivity, hostility, and child responsiveness was entered in the second step. Given the size of the sample and the scope of the study emphasizing the maternal sensitivity dimension more, the dimension of maternal structuring was excluded from the analysis to reduce the number of predictors. Doing so provided a minimum of 10 participants from each group per predictor variable as suggested by Tabachnik and Fidell (2001). Percent duration of time spent in each category of co-regulation composed the dependent variable. To increase power, the sub-categories were collapsed into their overarching categories described by Fogel et al. (2003). Specifically, the sequential and resonant sub-codes were collapsed into the overarching symmetrical code and the following, initiating, and demanding sub-codes were collapsed into the overarching unilateral code. Prior to conducting regressions, intercorrelations were examined to ensure that variables were not too highly correlated (Tabachnick & Fidell, 2001; see Tables 5-8 for intercorrelations). Only significant findings are reported in the text.

Full-term infant-mother dyads.

In the regression to address objective 3 in the normal period, examining EA and parenting stress as a predictor of symmetrical co-regulation, the overall model accounted for 43.9% (38% adjusted) of the total variance (Table 9). Mothers who were more sensitive engaged in more symmetrical patterns of co-regulation with their infants in the normal period (*Beta* = .45, $t = 2.42$, $p < .05$).

Addressing objective 3 in the reunion period, the regression examining EA and parenting stress as predictors of symmetrical co-regulation accounted for 45.9% (40.2% adjusted) of the total variance (Table 9). Infants with more adequate levels of responsiveness engaged in significantly more symmetrical co-regulation with their mothers (*Beta* = .58, $t = 3.87$, $p < .001$). The model examining EA and parenting stress as predictors of unilateral co-regulation accounted for 41.4% (35.3% adjusted) of the total variance (Table 11). Infants with lower levels of responsiveness engaged in greater amounts of unilateral co-regulation with their mothers (*Beta* = -.33, $t = -2.14$, $p < .05$). In the regression examining EA and parenting stress as predictors of disruptive co-regulation, the overall model accounted for 31.1% (23.8% adjusted) of the total variance (Table 12). Mothers with higher levels of parenting stress (*Beta* = .35, $t = 2.39$, $p < .05$) and infants with lower levels of responsiveness (*Beta* = -.38, $t = -2.26$, $p < .05$) engaged in significantly more disruptive co-regulation during the reunion period.

VLBW/preterm infant-mother dyads.

To address objective 3 in the normal period, the overall model for the regression examining EA and parenting stress as a predictor of symmetrical co-regulation accounted for 46.3% (40.6% adjusted) of the total variance (Table 9). Infants who were more appropriately responsive engaged in more symmetrical patterns of co-regulation with their mothers (*Beta* = .70, $t = 4.76$, $p < .001$). When the same regression was run with asymmetrical co-regulation as the dependent variable, the overall model accounted for 29% (21.5% adjusted) of the total variance (Table 10). Mothers who displayed less sensitivity towards their infants engaged in more asymmetrical co-regulation with their infants (*Beta* = -.45, $t = -2.04$, $p < .05$). When examining unilateral co-regulation as the dependent variable, the overall model accounted for 13.9% (4.9% adjusted) of the total variance (Table 11). Lower levels of responsiveness in infants was associated with significantly more unilateral co-regulation (*Beta* = -.42, $t = -2.30$, $p < .05$). When EA and parenting stress were entered as predictors of disruptive co-regulation the overall model accounted for 22.2% (14.1% adjusted) of the total variance (Table 12). Interestingly,

mothers who displayed higher levels of sensitivity (*Beta* = .63, $t = 2.74$, $p < .05$) and infants who displayed lower levels of responsiveness (*Beta* = -.42, $t = -2.39$, $p < .05$) engaged in more disruptive co-regulation with their infants in the normal period.

Addressing objective 3 in the reunion period, the regression examining EA and parenting stress as predictors of symmetrical co-regulation accounted for 28.9% (21.4% adjusted) of the total variance (Table 9). Infants with more adequate levels of responsiveness engaged in more symmetrical co-regulation with their mothers (*Beta* = .55, $t = 3.29$, $p < .05$). When asymmetrical co-regulation was entered as the dependent variable, the model accounted for 14.5% (5.5% adjusted) of the total variance (Table 10). Mothers with lower levels of sensitivity engaged in more asymmetrical co-regulation with their infants (*Beta* = -.59, $t = -2.41$, $p < .05$). A trend also emerged where mothers with lower levels of hostility (engaged in more non-hostile interactions) tended to asymmetrically co-regulate with their infants (*Beta* = .41, $t = 2.02$, $p = .05$). In the regression examining EA and stress as predictors of unilateral co-regulation, the overall model accounted for 17.2% (8.4% adjusted) of the total variance (Table 11). Infants who showed lower levels of responsiveness engaged in more unilateral co-regulation with their mothers (*Beta* = -.38, $t = -2.10$, $p < .05$). In the regression examining EA and parenting stress as predictors of disruptive co-regulation during the reunion period, the overall model accounted for 22% (13.7% adjusted) of the total variance (Table 12). Infants with lower levels of responsiveness engaged in more disruptive co-regulation with their mothers in the reunion period (*Beta* = -.46, $t = -2.60$, $p < .05$).

Discussion

The present study was designed to examine patterns of co-regulation between mothers and their 6-month-old full-term and VLBW/preterm infants during face-to-face interactions. The findings supported the hypotheses that time spent in different patterns of co-regulation would differ across birth status (group) and following a period of maternal emotional unavailability. As anticipated, co-regulation was also associated with various dimensions of the mother-infant relationship. These findings underscore the role of co-regulation and the quality of the mother-infant relationship in infants' social-emotional development.

The first objective was to investigate how patterns of co-regulation (i.e., symmetrical-sequential, symmetrical-resonant, asymmetrical, unilateral-following, unilateral-initiating, unilateral-demanding, and disruption) varied across normal interactions of the SF procedure. In

contrast to what was hypothesized, asymmetrical patterns of co-regulation were predominant across interaction periods. Although this finding contradicts previous research that higher levels of unilateral co-regulation are predominant (Hsu & Fogel, 2003), the current study may have captured a co-regulative transition occurring during the first year. Aurelius and Presaghi (2010) have reported that in the latter half of the first year, predominant mother-infant co-regulation shifts from unilateral to symmetrical. Perhaps infants undergoing this transition were orienting towards their mothers during interactions, but had not yet become active in the interaction. As was expected, dyads engaged in higher levels of unilateral (specifically, unilateral-initiating and, to a lesser extent, unilateral-demanding) co-regulation prior to the periods of maternal emotional unavailability. This finding indicates that 6-month-old infants may take a less-active role during face-to-face interactions with their mothers during normal, unperturbed interactions. Furthermore, in line with what was hypothesized, dyads engaged in more active forms of co-regulation (i.e., symmetrical-resonant and, to a lesser extent, symmetrical-sequential co-regulation) following the SF period. As hypothesized, greater levels of disruption in dyads' co-regulation also characterized the reunion interaction periods. Although infants may be more active in seeking regulation from their mothers, the mothers may not adhere to their infants' cues. In such instances, disruption would ensue. These findings suggest that following a period of maternal emotional unavailability infants seek out co-regulation to address this violation of social expectation. Such an interpretation is supported by previous research suggesting that infants engage in more attention-seeking behaviours and less resistant behaviour following the SF (Conradt & Ablow, 2011). However, because the SF can be a mild form of stress and there is a lack of co-regulation from mothers during this time, infants may become more difficult to soothe following the SF, resulting in greater negative affectivity, hence the increased disruption (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). Furthermore, as infants become increasingly difficult to soothe, mothers may misinterpret infant cues and thus not offer the particular comfort the infant is seeking. Sroufe (2011) comments that when caregivers display such difficulty in adhering to the cues of their infants over time in multiple interactions, difficult relationship patterns may arise.

The second objective was designed to examine differences in patterns of co-regulation between full-term and VLBW/preterm infant-mother dyads. Although, full-term and VLBW/preterm infant-mother dyads did not differ in the amount of symmetrical co-regulation

displayed, the nature of symmetrical co-regulation employed by each group differed. In line with what was hypothesized, full-term dyads spent more time in symmetrical-sequential forms of co-regulation, while VLBW/preterm infant-mother dyads spent more time in symmetrical-resonant co-regulation. These findings suggest that full-term infants are displaying more interaction skills and have a greater understanding of the back-and-forth nature of transactions than their VLBW/preterm counterparts. The symmetrical-resonant nature of VLBW/preterm infant-mother interactions could indicate that these infants are less able to regulate their emotional outbursts and adhere to the turn-taking nature of communication. Previous research has provided support for ongoing poor self-regulatory capabilities among VLBW/preterm infants across childhood (Clark, Woodward, Horwood, & Moor, 2008), which may adversely affect their roles in co-regulation. Full-term infants may have a better grasp at six months of the social rules that govern interactions than VLBW/preterm infants, thus resulting in a more structured approach characterized by back-and-forth interactions. Differences in reactions to social stimuli between full-term and VLBW/preterm infants have been demonstrated by Harel, Gordon, Geva, and Feldman (2011), who found that preterm infants displayed shorter periods of gaze synchrony with their mothers during interactions. Such differences may result in a slower grasp of social conventions. Surprisingly, with regard to disruption, there were no differences between groups. The lack of findings on disruption between groups may be due to the conservative nature of the VLBW/preterm group who displayed no medical problems aside from their birth status, and due to the correction for gestational age. As a result, the similarity between groups may have led to fewer differences in reactions to stress and difficulty to soothe.

The third objective was to investigate the association between co-regulation and the quality of the mother-infant relationship (as measured by the Emotional Availability scales), as well as the influence of parental stress. As was hypothesized, mothers of full-term, but not VLBW/preterm infants, who displayed higher levels of maternal sensitivity spent more time in symmetrical co-regulation during the initial interaction. Mothers high in sensitivity are known to provide warmth and are responsive to their infants' cues (Biringen et al., 2014). The current findings suggest that this warmth and responsivity allows infants to express themselves and respond to feedback from their mothers, leading to dyadic exchanges and forming the basis of communication. As such, infant responsiveness in both groups was also associated with more time spent in symmetrical co-regulation. Thus, both infant contributions to the interaction and

mothers' interpretations of those cues facilitate symmetrical co-regulation, encouraging both members to participate in the exchange. Past research has supported the positive relationship between symmetrical co-regulation and the infant's relationship with the caregiver. In a study by Evans and Porter (2009), greater time spent in symmetrical co-regulation at six months predicted infants' secure attachments to their caregivers at twelve months. Furthermore, mothers with securely attached infants have been shown to be highly sensitive to their infants' cues (Biringen et al., 2014), further enhancing the efficacy of infants' communication (Bronson, 2000). Conversely, as was hypothesized, mothers with lower levels of maternal sensitivity engaged in more asymmetrical interactions with their VLBW/preterm infants. In contrast to symmetrical co-regulation, asymmetrical co-regulation has been associated in previous studies with later insecure attachment patterns (Evans & Porter, 2009). Although, both members are engaged during asymmetrical co-regulation, the infant is not contributing to the interaction, potentially making it difficult for the relationship to progress. Importantly, this finding only appeared in the VLBW/preterm group, suggesting that at-risk dyads may be more vulnerable to the association between maternal sensitivity and their contributions to the interaction. Although not hypothesized, lower levels of maternal hostility were also associated with asymmetrical co-regulation in VLBW/preterm dyads. By refraining from hostility, mothers may have appeared more inviting to their infants, who then more willing to engage, if not actively participate.

In line with hypotheses, lower levels of infant responsiveness in both groups were associated with greater time spent in unilateral co-regulation. Furthermore, less responsive infants engaged in more disruption, as was hypothesized. These findings suggest that infants who are less responsive may have more difficulty expressing themselves and thus appear unengaged, or become upset when their cues are misinterpreted. According to Bronson (2000), infant responsivity develops through caregiver responses to infant social cues, allowing infants to see the efficacy of their modes of communication. When these efforts at communication are not addressed, infants become less responsive, as has been demonstrated in the literature on depressed mothers (Field, Diego, & Hernandez-Reif, 2009). Contrary to what was hypothesized, mothers displaying greater sensitivity to their VLBW/preterm infants engaged in more disruption during their interaction prior to the SF period. This finding is likely due to the low frequency of disruption in the sample. Furthermore, in unsuccessful attempts to soothe their upset infants,

mothers may have been employing behaviour characteristic of maternal sensitivity, which likely further inflated the association between sensitivity and disruption.

Consistent with predictions, mothers who reported experiencing higher levels of parental stress, as measured by the PSI (Abidin, 1995), engaged in more disruption of co-regulation with their full-term infants in the reunion periods. This finding supports the transactional model emphasizing bidirectional influences between infant, parent, and environment (Sameroff, 2009). Meeting the needs of a difficult to soothe baby and having difficulty interpreting the infants' cues can be a great source of stress for mothers. Conversely, increased stress may make it difficult to adhere to infants' cues and thus address them adequately (MacKenzie & McDonough, 2009). Surprisingly, no significant associations were found between parenting stress and disruption among VLBW/preterm dyads or between dimensions of EA and disruption, which may have been due to the low frequency of disruption demonstrated in the sample.

Limitations

The results from this study made some important contributions, namely the impact of a mild stressor and risk status on co-regulation and the association between co-regulation and quality of the caregiver-infant relationship. However, a few limitations should also be acknowledged. As was alluded to, the VLBW/preterm sample was gathered using strict exclusionary criteria so as to only include medically healthy infants (aside from their birth status as VLBW/preterm). This criterion allows for greater confidence in associated differences in co-regulation to birth status, however, it may be an underestimation of the differences between many VLBW/preterm infants and full-term infants in the general population. Many VLBW/preterm infants, in part due to their difficult birth status, experience a number of other medical problems (McCormick, Litt, Smith, & Zupancic, 2011), which were not accounted for in this study and could potentially contribute to co-regulation and the quality of the mother-infant relationship, as well as to parenting stress. Furthermore, although the procedures took place in a naturalistic setting (i.e., in the homes of participants), the SF procedure itself is prone to some limitations. First, the infant is placed in a car seat, which restricts their movement (so as to keep the interaction in a face-to-face format). However, placing the infant in a car seat also allows for rich observations during a short period of time by helping to keep the dyad focused on the interaction. Second, although naturalistic, the camera and mirror were in many cases novel objects to the infants and sometimes became a distraction to the infants' focus of attention.

However, this was not a common occurrence and often provided an opportunity to observe how mothers re-directed their infants back to the interaction. Third, the SF period is an unusual situation for both infants and mothers that may change their mode of interaction. Nevertheless, the unusual nature of the SF provided an impetus for dyads to co-regulate as a means to recover from the arousal induced and further illustrated the nature of the dyads' co-regulative patterns. Furthermore, a natural period of interaction occurred prior to the SF, which provided insight into how the dyad interacted under more natural circumstances.

Future Directions

This study was the first to examine co-regulation in full-term and VLBW/preterm infant-mother dyads as a function of the quality of the mother-infant relationship (i.e., using the Emotional Availability scales). Variations in methodology will allow future research to add to the growing literature on co-regulation in both low- and high-risk populations. Infancy is a time of large transitions, particularly in the development of communication and social exchanges. Previous research has demonstrated developmental changes in predominant patterns of co-regulation between infants and their mothers during the first two years of life, noting a change from unilateral to symmetrical co-regulation (Aureli & Presaghi, 2010; Evans & Porter, 2009). These findings point to the need for longitudinal studies of co-regulation over the first years of life to account for how changes in patterns of co-regulation compare between full-term and VLBW/preterm infant samples, as well as the association between co-regulation and the parent-infant relationship over time. Furthermore, additional contexts (beyond face-to-face paradigms) should be examined to determine how situational factors might impact mother-infant co-regulation. In the middle of the first year of life, infants and their mothers increase their inclusion of objects in their interactions (De Schuymer, De Groote, Striano, Stahl, & Roeyers, 2011). Therefore, future research would benefit from encompassing this developmental stage within their methodological framework to enhance the naturalistic setting. That said, face-to-face interactions are common and peak at this age, particularly during floor play and when infants are seated (Field, Vega-Lahr, Goldstein, & Scafidi, 1987; Jean, Stack, Girouard, & Fogel, 2004).

While the present study sample focuses on full-term and VLBW/preterm dyads, samples including a wide array of vulnerable dyads, including those who are socio-economically and psychosocially at-risk, should be examined in relation to parent-infant relationship quality and co-regulation. VLBW/preterm infants have been shown to display more problems in social

relations than their full-term counterparts (Smith & Ulvund, 2003). Therefore, it is imperative to examine the precursors of social development within this population via avenues such as co-regulation. Moreover, given the relationship of parental stress and the tendency to not adhere to partner cues in a mother-infant interaction, further research should examine the role of parenting stress and other contextual variables in co-regulation and processes of interactions. Finally, the sample of VLBW/preterm infants should be expanded to include infants with medical problems aside from their birth status to discern how these problems may complicate co-regulation.

Conclusions

Taken together these findings contribute to the study of co-regulation between mother-infant dyads and the quality of their relationships. The results add to past findings demonstrating differences in regulatory abilities between full-term and VLBW/preterm infants and changes following a mild social stressor by examining how the dyad as a whole regulates. Furthermore, the findings emphasize the importance of investigating interactions from a dyadic perspective. The results show support for the notion that following social violations by their mothers reflected in the SF period, infants take on a more active role in co-regulating the interaction. Specifically, full-term infants tend to adopt a more structured approach characterized by back-and-forth exchanges, while VLBW/preterm infants take on more spontaneous bursts of emotion during interactions with their mothers. Furthermore, the transactional model of development is reflected in the findings as maternal warmth and responsiveness appears to facilitate infants' active engagement with their mothers, just as infant responsiveness contributes to a more dyadic interaction. Finally, parental stress appeared to have a stronger association with full-term mother-infant misinterpretation of cues than it did with the VLBW/preterm sample.

Together, these results illustrate the dyadic nature of mother-infant interactions and have implications for the development of positive relationships in infants. Whenever two people are interacting, they are engaging in some form of co-regulation. Thus, the early development of infant-mother co-regulation may have a profound impact on infants' relationships as they develop later in life. The findings of the current study underscore important co-regulative differences between low- and higher-risk groups. Further study on co-regulation in high-risk mother-infant dyads hold promise for a better understanding of how to ensure that those who are most vulnerable are able to develop healthy relationships and thus build the social capital necessary to foster quality of life.

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Figure 1

Percent duration of type of co-regulation for normal and reunion periods collapsed across group

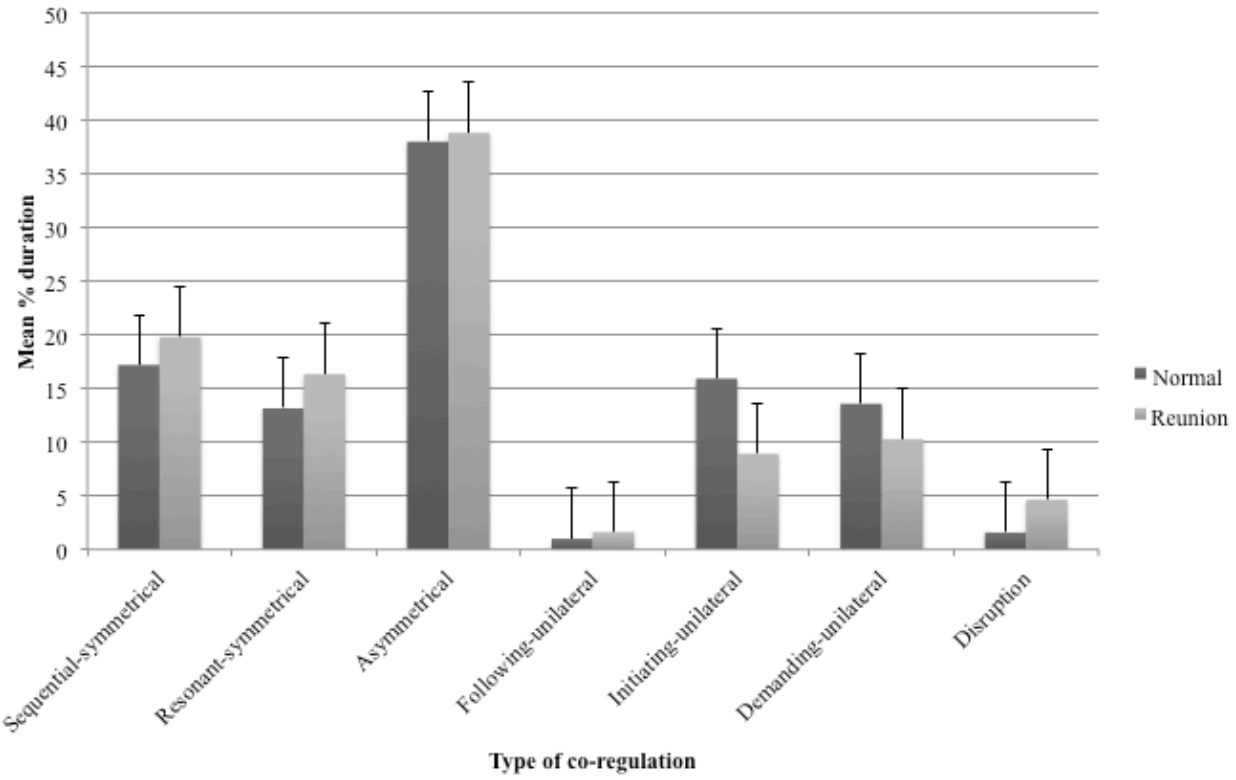

Figure 2

Percent duration of type of co-regulation for full-term and VLBW/preterm infant-mother dyads collapsed across interaction periods

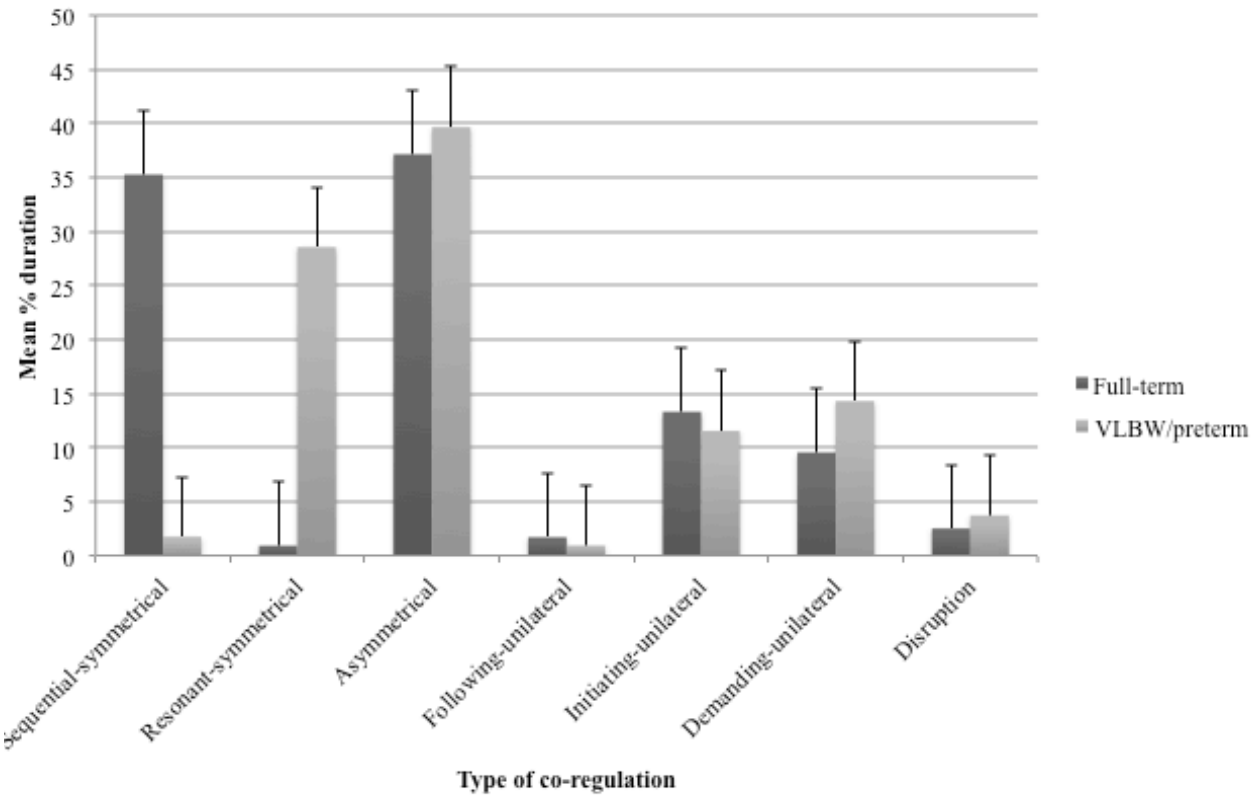

Table 1

Demographic and medical information

	Full-term (n = 43)		VLBW/preterm (n = 44)	
	M	*SD*	*M*	*SD*
Maternal age at birth (years)	30.09	5.30	31.73	6.03
Maternal education at birth	14.77	1.89	12.98	2.12
Infant birth weight (grams)	3463.12	427.93	1109.89	241.04
Infant gestational age (weeks)	39.53	1.14	28.48	2.15
Emergency C-section (%)	9.30		68.20	
1 min. APGAR	8.61	1.02	6.19	2.12
5 min. APGAR	9.22	0.57	7.93	1.37
Length of hospital stay (days)	3.91	4.24	61.59	29.49
Infant length at birth (cm)	50.55	4.57	37.57	3.45
Infant head circumference (cm)	34.95	1.60	26.66	2.18
Infant weight at 6 months (grams)	6812.00	969.70	6680.00	1084.00
Infant height at 6 months (cm)	64.07	4.33	62.73	3.65

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2

Inclusion and exclusion criteria for VLBW/preterm infants

Inclusion criteria	Exclusion criteria
Between 26 and 30 weeks of age	Diagnosis of a major congenital abnormality or defect
Birth weight between 800 and 1500 g	Experienced a Grade IV or III intra-ventricular hemorrhage or other major medical complications, illnesses or syndromes, such as hydrocephalus, severe neurological impairment, or those with hearing loss, retinopathy
Age in weeks, birth weight, and head circumference within 2 *SD*	Prolonged hospitalization since neonatal period
Living with biological mother	Multiple hospitalizations since the neonatal period
Mother speaks English or French	Mothers at psychosocial risk due to a history of inadequate prenatal care, drug abuse, mental illness, etc.

Table 3

Operational definitions for the Revised Relational Coding System (Fogel et al., 2003)

	Operational definition	Kappa	ICC
Symmetrical	Both members are engaged and contributing to the interaction. Their behaviours are modified based on interpretation of the cues of the partner.	0.85	0.944
Sequential	Both members contribute to the interaction in a fluid and structured manner. The interaction is characterized by back-and-forth conversational nature.	0.66	0.91
Resonant	Spontaneous contributions from either member occur and are responded to by their partners.	0.80	0.89
Asymmetrical	Both members are engaged with a common point of interest. Only one member of the dyad is actively making contributions to the interaction, while the partner observes	0.76	0.94
Unilateral	One member is engaged and may or may not contribute to the interaction. Their partner does not take interest, contribute to the interaction, or account for the other member in their actions.	0.84	0.98
Following	The engaged member of the dyad observes the behaviour of the partner without attempting to engage the partner.	0.62	0.99
Initiating	The engaged member attempts to bring the unengaged partner into the interaction non-intrusively. However, attempts to engage the partner are unsuccessful.	0.71	0.95
Demanding	The engaged member takes a more active approach to bring the unengaged partner into the interaction. These approaches are characterized by intrusiveness as the engaged member encroaches upon their partner's personal space. The unengaged partner remains uninterested despite the other member's attempts to grab their attention.	0.76	0.89
Disruption	The interaction is characterized by a lack of adherence to cues of displeasure within the dyad. One member becomes upset, while the partner fails to act in a manner that addresses the other member's regulative and behavioural needs.	0.86	0.99

Table 4

Mean percent duration and standard deviations of co-regulation variables in the normal and reunion periods

	Full-term		**VLBW/preterm**	
	Normal	Reunion	Normal	Reunion
Symmetrical	32.71 (22.63)	39.66 (23.69)	28.54 (22.03)	33.26 (21.79)
Sequential	32.38 (22.059)	38.16 (23.41)	1.65 (4.51)	1.17 (3.39)
Resonant	0	1.16 (2.82)	25.96 (20.82)	31.16 (21.59)
Asymmetrical	37.20 (20.14)	37.12 (19.11)	38.80 (17.75)	40.50 (17.44)
Unilateral	28.37 (21.85)	20.76 (21.89)	31.20 (24.06)	20.59 (21.81)
Following	0.53 (1.36)	1.56 (4.98)	1.04 (2.48)	0.73 (1.60)
Initiating	16.40 (16.14)	8.55 (8.11)	15.20 (16.09)	7.88 (8.84)
Demanding	10.81 (13.85)	7.54 (8.89)	16.03 (18.38)	12.25 (14.86)
Disruption	1.29 (3.88)	1.72 (3.36)	0.50 (1.90)	5.97 (11.17)

SD in parentheses

Table 5

Correlations between types of co-regulation, parental stress, and emotional availability in full-term dyads during the normal period

	Co-regulation				Emotional availability			Parental stress
	1	2	3	4	5	6	7	8
Co-regulation								
1. Symmetrical	1.00							
2. Asymmetrical	-0.36*	1.00						
3. Unilateral	-0.58***	-0.50**	1.00					
4. Disruption	-0.37*	-0.16	0.19	1.00				
Emotional availability								
5. Maternal Sensitivity	0.56***	-0.11	-0.40**	-0.22	1.00			
6. Maternal Non-hostility	0.081	-0.12	0.03	-0.008	-0.50**	1.00		
7. Child Responsiveness	0.59***	-0.05	-0.45**	-0.31*	0.65***	0.17	1.00	
8. **Parental stress**	-0.14	-0.14	0.27	0.02	0.04	0.14	-0.06	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6

Correlations between types of co-regulation, parental stress, and emotional availability in full-term dyads during the reunion period

	Co-regulation				Emotional availability			Parental stress
	1	2	3	4	5	6	7	8
Co-regulation								
1. Symmetrical	1.00							
2. Asymmetrical	-0.47**	1.00						
3. Unilateral	-0.59***	-0.39*	1.00					
4. Disruption	-0.28	0.08	-0.08	1.00				
Emotional availability								
5. Maternal Sensitivity	0.46**	0.04	-0.54***	0.03	1.00			
6. Maternal Non-hostility	0.33*	0.05	-0.40**	0.01	0.42**	1.00		
7. Child Responsiveness	0.64***	-0.06	-0.52***	-0.37*	0.52***	0.20	1.00	
8. **Parental stress**	-0.07	-0.15	0.06	0.46**	0.03	0.20	-0.30	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7

Correlations between types of co-regulation, parental stress, and emotional availability in VLBW/preterm dyads during the normal period

	Co-regulation				Emotional availability			Parental stress
	1	2	3	4	5	6	7	8
Co-regulation								
1. Symmetrical	1.00							
2. Asymmetrical	-0.23	1.00						
3. Unilateral	-0.69***	-0.53***	1.00					
4. Disruption	-0.08	0.15	-0.22	1.00				
Emotional availability								
5. Maternal Sensitivity	0.36*	-0.47**	-0.02	0.21	1.00			
6. Maternal Non-hostility	0.18	-0.33*	0.07	0.04	0.74***	1.00		
7. Child Responsiveness	0.67***	-0.27	-0.36*	-0.16	0.56***	0.45**	1.00	
8. **Parental stress**	-0.13	0.27	-0.10	0.13	-0.34*	-0.37*	-0.21	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8

Correlations between types of co-regulation, parental stress, and emotional availability in VLBW/preterm dyads during the reunion period

	Co-regulation				Emotional availability			Parental stress
	1	2	3	4	5	6	7	8
Co-regulation								
1. Symmetrical	1.00							
2. Asymmetrical	-0.37*	1.00						
3. Unilateral	-0.62***	-0.29	1.00					
4. Disruption	-0.17	-0.24	-0.23	1.00				
Emotional availability								
5. Maternal Sensitivity	0.28	-0.16	-0.00	-0.25	1.00			
6. Maternal Non-hostility	0.18	0.10	-0.19	-0.12	0.67***	1.00		
7. Child Responsiveness	0.53***	-0.00	-0.26	-0.48**	0.58***	0.34*	1.00	
8. **Parental stress**	-0.00	-0.05	-0.09	0.24	-0.41**	-0.19	-0.27	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9

Parental stress and emotional availability predicting symmetrical co-regulation

		Full-term								VLBW/preterm							
		Normal				Reunion				Normal				Reunion			
		R^2_{ch}	*Beta*	Sr^2	*t*	R^2_{ch}	*Beta*	Sr^3	*t*	R^2_{ch}	*Beta*	Sr^4	*t*	R^2_{ch}	*Beta*	Sr^5	*t*
Predictor																	
Step 1		0.02				0.02				0.071				0.00			
	PSI		-0.14	-0.14	-0.90		-0.15	-0.15	-0.94		0.27	0.27	1.77		-0.050	-0.050	-0.32
Step 2		0.01				0.03				0.22				0.14			
	PSI		-0.13	-0.13	-0.78		-0.23	-0.21	-1.31		0.12	0.11	=0.83		-0.18	-0.16	-1.090
	Maternal sensitivity		-0.08	-0.05	-.33		-0.11	0.09	0.59		-0.45	-0.28	-2.035*		-0.59	-0.36	-2.41*
	Maternal hostility		-0.06	-0.05	-.32		-0.10	0.08	0.60		0.12	0.080	0.59		0.41	0.30	2.021t
	Child Responsiveness		-0.01	-0.01	0.03		-0.20	-0.16	0.32		-0.18	-0.15	-1.082		0.12	0.095	0.63
R^2adj		-0.07				-0.05				0.22				0.06			
N		43				43				44				44			

*$p < 0.05$, **$p < .01$, ***$p < .001$

Table 10

Parental stress and emotional availability predicting asymmetrical co-regulation

		Full-term								VLBW/preterm							
		Normal				Reunion				Normal				Reunion			
		R^2_{ch}	*Beta*	Sr^2	*t*	R^2_{ch}	*Beta*	Sr^3	*t*	R^2_{ch}	*Beta*	Sr^4	*t*	R^2_{ch}	*Beta*	Sr^5	*t*
Predictor																	
Step 1		0.02				0.02				0.071				0.00			
	PSI		-0.14	-0.14	-0.90		-0.15	-0.15	-0.94		0.27	0.27	1.77		-0.050	-0.050	-0.32
Step 2		0.01				0.03				0.22				0.14			
	PSI		-0.13	-0.13	-0.78		-0.23	-0.21	-1.31		0.12	0.11	=0.83		-0.18	-0.16	-1.090
	Maternal sensitivity		-0.08	-0.05	-.33		-0.11	0.09	0.59		-0.45	-0.28	-2.035*		-0.59	-0.36	-2.41*
	Maternal hostility		-0.06	-0.05	-.32		-0.10	0.08	0.60		0.12	0.080	0.59		0.41	0.30	2.021t
			-0.01	-0.01	0.03		-0.20	-0.16	0.32		-0.18	-0.15	-1.082		0.12	0.095	0.63
	Child responsiveness																
R^2adj		-0.07				-0.05				0.22				0.06			
N		43				43				44				44			

*$p < 0.05$, **$p < .01$, ***$p < .001$

Table 11

Parental stress and emotional availability predicting unilateral co-regulation

		Full-term								VLBW/preterm							
		Normal				Reunion				Normal				Reunion			
		R^2_{ch}	*Beta*	Sr^2	*t*	R^2_{ch}	*Beta*	Sr^3	*t*	R^2_{ch}	*Beta*	Sr^4	*t*	R^2_{ch}	*Beta*	Sr^5	*t*
Predictor																	
Step 1		0.071				0.00				0.017				0.00			
	PSI		0.27	0.27	1.77		0.061	0.061	0.39		-0.13	-0.13	-0.83		-0.00	-0.00	-0.024
Step 2		0.25**				0.41***				0.45				0.29			
	PSI		0.23	0.23	1.73		0.017	0.016	0.13		-0.035	-0.032	-0.27		0.15	0.14	1.021
	Maternal sensitivity		-0.37	-0.24	-1.79		-0.27	-0.21	-1.71		0.14	0.088	0.74		0.022	0.014	0.099
	Maternal hostility		0.22	0.19	1.40		-0.23	-0.20	-1.65		-0.27	-0.17	-1.47		-0.010	-0.010	-0.054
			-0.24	-0.17	-1.30		-0.33	-0.27	-2.14*		0.70	0.57	4.76***		0.55	0.45	3.29**
	Child responsiveness																
R^2adj		0.25				0.35				0.41				0.21			
N		43				43				44				44			

*$p < 0.05$, **$p < .01$, ***$p < .001$

Table 12

Parental stress and emotional availability predicting disruption

		Full-term								VLBW/preterm							
		Normal				Reunion				Normal				Reunion			
		R^2_{ch}	*Beta*	Sr^2	*t*	R^2_{ch}	*Beta*	Sr^3	*t*	R^2_{ch}	*Beta*	Sr^4	*t*	R^2_{ch}	*Beta*	Sr^5	*t*
Predictor																	
Step 1		0.071				0.00				0.017				0.00			
	PSI		0.27	0.27	1.77		0.061	0.061	0.39		-0.13	-0.13	-0.83		-0.00	-0.00	-0.024
Step 2		0.25**				0.41***				0.45				0.29			
	PSI		0.23	0.23	1.73		0.017	0.016	0.13		-0.035	-0.032	-0.27		0.15	0.14	1.021
	Maternal sensitivity		-0.37	-0.24	-1.79		-0.27	-0.21	-1.71		0.14	0.088	0.74		0.022	0.014	0.099
	Maternal hostility		0.22	0.19	1.40		-0.23	-0.20	-1.65		-0.27	-0.17	-1.47		-0.010	-0.010	-0.054
			-0.24	-0.17	-1.30		-0.33	-0.27	-2.14*		0.70	0.57	4.76***		0.55	0.45	3.29**
	Child responsiveness																
R^2adj		0.25				0.35				0.41				0.21			
N		43				43				44				44			

*$p < 0.05$, **$p < .01$, ***$p < .001$