Co-regulation between mothers and children over time and in different risk contexts

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A Thesis

In the Department

of Psychology

Presented in Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy (Psychology) at

Concordia University

Montreal, Quebec, Canada

January 2023

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: **Co-regulation between mothers and children over time and in different risk contexts**

and submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (PSYCHOLOGY)

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ABSTRACT

Co-regulation between mothers and children over time and in different risk contexts

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This dissertation explored the development and outcomes of mother-infant co-regulation of communication in low- and at-risk dyads. Interactions between mothers and their children were observationally coded for co-regulation when children were 6-, 12-, 18-, and 48-months-old based on their level of engagement and contribution to the interaction. Further information was gathered about parenting stress, demographics, and children's internalizing and externalizing symptoms (at 4 and 7 years of age).

The participants in both studies comprised three groups of mother-infant dyads with varying levels of risk. They included the low-risk full-term group, the at-risk very low birthweight (VLBW)/preterm group, and the psycho-socially at-risk group whose mothers had childhood histories of adversity. In both studies, free-play interactions between mothers and their infants were coded for patterns of co-regulation.

Longitudinal results from multi-level modelling in Study 1 indicated that for low- and at-risk groups, dyads generally became increasingly synchronous and less asynchronous over time. However, VLBW/preterm boys whose mothers reported higher levels of parenting stress interacted more asynchronously over time. In contrast, psycho-socially at-risk dyads whose mothers reported more parenting stress interacted less asynchronously over time.

The interaction of co-regulation and parenting stress and its association with children's internalizing and externalizing symptoms in early and middle childhood were explored in Study 2, using moderation analyses. Results showed that co-regulation had different moderating effects in low- and at-risk groups. Among low-risk dyads who engaged in more asynchronous patterns

of co-regulation, parenting stress was associated with more child internalizing symptoms. However, among both groups of at-risk dyads who engaged in low levels of asynchronous patterns of co-regulation, parenting stress was associated with more child internalizing and externalizing symptoms. Further investigation of the psycho-socially at-risk group in middle childhood revealed that this moderation effect extended longitudinally.

Findings from both studies are discussed in the context of Dynamic Systems (Fogel, 1993) and Transactional Models (Sameroff, 2009) approaches to social-emotional development. These results make significant contributions to our understanding of co-regulation in adverse circumstances and highlight its contribution to fostering healthy parent-child relationships. Importantly, this dissertation underscores consideration of context in the development of co-regulation.

Acknowledgements

The road to completing this thesis has highlighted my incredible support system of family, friends, mentors, and colleagues. Each has helped me so much along the way.

To my supervisor, Dr. Dale M. Stack, thank you for your patient guidance and mentorship. Your warm support and kindness were hallmarks of working with you. Unsurprisingly, you have also managed to put together an amazing group of research coordinators, assistants, and volunteers. A huge thank you goes out to those members of the Stack Lab, for their many hours of coding and assistance. I'd also like to thank the families who volunteered their time to participate in these studies.

To my committee members, Drs. Nina Howe and Erin Barker, thank you for your valuable insights, encouragement, and enthusiasm for this project.

To the Stackies, thank you for welcoming me with open arms when I moved to Montreal and continuing to provide me with a healthy dose of laughs, sarcasm, chocolate, and themed birthday parties. To members of my cohort (and beyond) who added to these laughs, nursed me through my injuries, and always had my back – thank you. These are the memories I will always keep close.

Thank you to my parents who continue to support me in every way they can. From the moment I told them I would go into psychology, they steadfastly supported me through many moves, vague timelines, and occasional mishaps, as they always have. Mom and Dad, this journey would not have been possible without you. Thank you also to Jeff and Anne for their encouragement every step of the way.

To Tom, thank you for believing in me, especially in moments when I didn't believe in myself. I love you, and here's to many more adventures together.

Contribution of Authors

The current dissertation consists of two manuscripts:

Study 1 (see Chapter 2)

Doiron, K. M., Stack, D. M., Dickson, D. J., Bouchard, S., & Serbin, L. A. (2022). Co-regulation and parenting stress over time in full-term, very low birthweight preterm, and psychosocially at-risk infant-mother dyads: Implications for fostering the development of healthy relationships. *Infant Behavior and Development, 68,* 101731. https://dx.doi.org/10.1016/j.infbeh.2022.101731

Study 2 (see Chapter 4)

Doiron, K. M., Stack, D. M., De France, K., Serbin, L. A. (manuscript in preparation). Moderating effects of mother-child co-regulation on the association between parent stress and child mental health in pre-schoolers in low- and at-risk dyads.

My supervisor, Dr. Dale M. Stack and I are responsible for the conceptualization of the research outlined in both studies of this dissertation. The data used in both studies were collected from two sources. The low-risk full-term and very low birthweight (VLBW)/preterm dyads were collected in conjunction with the Neonatal Intensive Care Unit at a large teaching hospital in the Montreal area by research staff in Dr. Stack's Infant and Child Studies Laboratory. The psychosocially at-risk dyads were initially recruited through the Concordia Longitudinal Research Project (Concordia Project), under the direction of Drs. Jane Ledingham and Alex E. Schwartzman. The project is currently under the direction of Drs. Lisa A. Serbin Concordia University) and Dale M. Stack of Concordia University.

Observational coding for both studies was completed by me in Dr. Stack's Infant and Child Studies Laboratory at Concordia University. A significant portion of the observational coding and data management was also completed by Samantha Bouchard (Study 1), former research assistant in Dr. Stack's laboratory. Some additional coding was carried out with assistance from undergraduate students. Following the reliability and observational coding, I completed data entry and cleaning procedures using statistical software. With guidance and input from Dr. Stack, I formulated the research questions, and hypotheses. Daniel Dickson (Study 1) and Kalee De France (Study 2), former post-doctoral researchers in Drs. Stack and Serbin laboratories, provided guidance on planning and executing analyses, as well as input on the interpretation of the results. I wrote all components of this dissertation. Dr. Stack provided feedback throughout the entire process, including revisions and edits to the text.

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Chapter 1: General Introduction

During social interactions people are expected to manage their behavior in response to others. Social cues such as body language, facial expressions, eye contact, and tone and content of speech shape how others respond. Communication is facilitated when social cues are understood and responded to appropriately by each person in the interaction (Biringen et al., 2014). When these cues are misunderstood or ignored, communication breaks down. The constant management of social interactions begins early in life and is termed, *co-regulation*. During co-regulation, people adjust their behavior, affect, and expressions based on feedback from others with the goal of facilitating communication (Fogel, 1993). This co-regulative process affects the ways others respond and vice versa. In relationships between mothers and children, maternal, child, and environmental factors contribute to co-regulation (Sameroff, 2009). For example, research using Tronick's (1978) Still-Face procedure, whereby mothers assume a neutral expression and refrain from talking or touching their infants during a brief period, has shown that infants display more negative affectivity in this period of maternal emotional unavailability (Adamson & Frick, 2003). Furthermore, mothers interact more intrusively with children who were born prematurely than those in low-risk situations (Muller-Nix et al., 2004). Likewise, mothers with childhood histories of aggression and social withdrawal displayed higher levels of hostility towards their children (Stack et al., 2012). Previous research has focused on the maternal role in social interactions, often overlooking children's abilities to influence their mother's behavior and the role of risk in this process (Fogel, 1993; Sameroff, 2009). Therefore, this dissertation was designed to investigate how mothers *and* their children shape their play together, how their interactions change over time and how they differ based on level of risk and parenting stress, and associated outcomes in children's mental health.

Overview of Co-Regulation

Infants enter the world dependent upon their caregivers for the necessities of life and to help regulate their internal states (Bronson, 2000). These internal states include not only physical discomfort such as hunger, pain, and fatigue, but also emotional arousal. Contrary to early assumptions that infants were passive recipients of care, research now indicates that infants play active roles in their relationships with caregivers (Fogel, 1993; Lamb, 1977; Sameroff, 2009). For example, in sensitive and responsive infant-mother relationships, infants communicate their discomfort through crying, emotional expressions, and movements to elicit responses from their caregivers (Bronson, 2000). This sequence of events – infant cries, caregiver responds, and infant's arousal decreases – is an early form of co-regulation. In other words, caregivers co-regulate their infants' arousal by listening, interpreting and anticipating their infants' behavior, and addressing their needs. While addressing their infants' needs, caregivers must continue to monitor their own behavior, as well as their infants' behavior for indications that the needs have been met. Likewise, infants co-regulate interactions by initially expressing discomfort, then responding to their caregivers' efforts to communicate satisfaction or dissatisfaction (Bronson, 2000). This process will shape expectations for future interactions between mothers, infants, and others throughout the course of their relationship (Fogel, 1993).

As highlighted in the example above, co-regulation plays a crucial role in infants' developing emotion regulation capacities. However, emotions are only one aspect of co-regulation. While emotion regulation can be either a joint (via co-regulation) or individual endeavor, co-regulation always involves 2 or more people (Fogel, 1993). Furthermore, optimal co-regulation, which maximizes communication, involves the regulation of behaviors, vocalizations, movements, expectations, and memories of the relationship, as well as emotions

(Fogel, 1993). It requires a focus on the relationship, rather than solely on one's own internal states.

As infants develop into childhood and adulthood, they develop strategies to regulate their internal states and rely less on co-regulation of those states from their caregivers, in other words, they become more adept at emotion regulation (Bronson, 2000). However, co-regulation of communication continues to be important for social interactions, regardless of age. Whenever people engage in conversations, they must continually monitor, interpret, and anticipate social cues from each other and shape their responses accordingly, just as caregivers do when responding to their infants' cries (Fogel, 1993). Behavior informed by correctly interpreted social cues facilitates communication, while misinterpretation of social cues and subsequent behavior leads to miscommunication and inappropriate responses (Fogel et al., 2003). Importantly, although one partner may be more engaged or active in the interaction, both interactive partners co-regulate their communication and are responsible for how it unfolds (Fogel et al., 2003).

Fogel and colleagues identified three overarching patterns of co-regulation observed in caregiver-infant communication that can be applied across the lifespan: symmetrical, asymmetrical, and unilateral (Fogel et al., 2003; Fogel & Lyra, 1997; Fogel et al., 1996; Hsu & Fogel, 2001). During *symmetrical* co-regulation, both caregiver and infant are engaged and contribute to their interaction. Each pays careful attention to the ongoing interaction, interprets and anticipates cues correctly, and contributes to the interaction accordingly. During *asymmetrical* co-regulation, one member of the dyad – usually the caregiver during infancy and early childhood – carries the interaction, while the engaged infant watches on. The infant remains a passive observer, despite invitations from their caregiver to contribute to the interaction. During *unilateral* co-regulation one member – usually the infant or young child – is

unengaged from their caregiver, as indicated by a lack of eye contact, vocalizations, or movements towards their caregiver. In response, their caregiver either watches the infant silently or attempts, unsuccessfully, to re-engage the infant. Disruptive and unengaged interactive patterns indicate a lack of co-regulation. Disruptive interactions occur when caregiver and infant do not adhere to each other's cues, and unengaged interactions occur when neither caregiver nor child is engaged with the other (Fogel et al., 2003). These patterns of co-regulation break down further into 7 sub-codes; however, the dissertation studies focused on the 3 aforementioned overarching patterns, as well as disruptive and unengaged interactions during mother-infant interactions. While co-regulation occurs during all interactions, the present dissertation focuses on mother-infant interactions, as much of the past literature has largely focused on interactions between mothers and infants (e.g., Evans & Porter, 2009; Provenzi et al., 2018; Sansavini et al., 2015).

Results from prior research have shown that mothers and infants show more symmetrical and unengaged, and less unilateral co-regulation over the first year of life (Evans & Porter, 2009). Mother-infant dyads also show a curvilinear pattern of asymmetrical co-regulation, with an initial decrease of asymmetrical co-regulation from 6 to 9 months and an increase from 9 to 12 months (Evans & Porter, 2009). In contrast, other researchers have observed the predominance of unilateral co-regulation in the second year but describe a similar trend of decreasing unilateral and increasing symmetrical co-regulation (Aureli & Presaghi, 2010). Within symmetrical co-regulation mother-infant dyads begin with shared affect and actions, then develop into shared language as infants build their language skills (Aureli & Preaghi, 2010). Importantly, predominant patterns of co-regulation at 6 months have implications for the mother-infant relationship and infant development at 12 months (Evans & Porter, 2009). Dyads that

engaged in more symmetrical co-regulation at 6 months had more secure relationships and infants showed better psychomotor and mental development at 12 months (Evans & Porter, 2009). While these studies provide insight into early developmental patterns of mother-infant co-regulation and the influences co-regulation may have on later infant development, there is a paucity of research examining co-regulation beyond the first two years of life. In addition, researchers have neglected high- and at-risk groups that may show different patterns in, and consequences of co-regulative development.

Theoretical Approach

The concept of co-regulation of communication is embedded in Dynamic Systems Theory, which asserts that social interactions are in constant flux and must continually adapt with multiple interacting factors (Fogel, 1993). These factors include each person's past experiences, expectations, interpretations of the interactive partner's responses, and current needs and wants that each partner seeks to communicate. The goal of co-regulation is synchrony of the dyadic partners to facilitate communication. When dyadic partners are in synchrony, they communicate their needs clearly, respond appropriately to their partner, and their expectations for the interaction are met. This requires sensitivity and responsivity from each dyadic partner. Fogel (1993) describes synchronous interactions as a "dance" whereby dyadic partners must anticipate and respond to the movements – or behaviors – of the partner. Given the constant mutual influences between dyadic partners, Fogel (1993) posits that the interaction – or dyad – itself should be examined, rather than the discrete behaviors of each person when investigating developing relationships. Thus, patterns of how the interaction is co-regulated are an important piece of Dynamic Systems Theory, as these patterns encompass behaviors of each dyadic partner (i.e., mother and infant).

Transactional Models consider both mutual influences between the mother and infant, as well as broader environmental influences on the dyad (Sameroff, 2009). Unlike previous approaches, that focused on maternal influences on the child, Transactional Models account also for influences of children on their mothers (Lamb, 1977; Sameroff, 2009). For example, although parenting behaviors impact child behaviors (Paulussen-Hoogeboom et al., 2008), child temperament and behavior have also been shown to influence parenting behaviors, which further impacts child behaviors (Lengua & Kovacs, 2005). Thus, to better understand the complexities of mother-infant relationships, research methodologies must account for the bidirectional influences between the mother and the infant. Furthermore, mothers and their children do not live in a vacuum, but rather, in a complex ecological system (Bronfenbenner, 1977). Therefore, a comprehensive model must also account for the dyad's environment (Sameroff, 2009). This includes both how members of the dyad are shaped by their environment, and how each member actively shapes their environment. For example, low socioeconomic status (SES) – one aspect of the environment – consistently predicts maladaptive outcomes including parenting stress, child behavior problems, and lower child academic achievement (Davis-Kean, 2005; Dodge et al., 1994; Mackler et al., 2015). Conversely, parents and children also shape their environments, such as when children select their peer groups. For example, research indicates that children with conduct problems tend to associate more with deviant peers (Farmer et al., 2003), which in turn leads them to engage in more risk-seeking behaviors (Siraj et al., 2021). Therefore, to understand the trajectories of child development, it is crucial to investigate the ongoing transactions between parents, children, and the environment, particularly in vulnerable populations.

Dynamic Systems Theory and Transactional Models follow similar principles of bidirectional influences. While Dynamic Systems Theory focuses on the moment-to-moment

exchanges that occur during social interactions, it also acknowledges that a history of interactions within specific environments shape present interactions (Fogel, 1993). Likewise, Transactional Models account for the constant bidirectional exchanges between mother-child dyads *and* their environment (Sameroff, 2009). Both theories posit that the development of social interactions is best understood using a method that accounts for these mutual influences (Fogel, 1993; Sameroff, 2009). Taken together, Dynamic Systems and Transactional Models are appropriate theories to guide the present studies and from which to examine the complexities of co-regulation.

Development of Social Interactions

In line with a Dynamic Systems approach, and as noted earlier, child, parent, and environmental factors contribute to the development of social interactions. From birth infants are motivated to engage with others by attending more to people with direct gazes than those with averted gazes (Bornstein & Tamis-LeMonda, 2010; Farroni et al., 2002). Throughout the first two years of life, infants' attentional capacities and understanding of others' intentions expand rapidly, allowing infants to be more active in their social interactions (Bornstein & Tamis-LeMonda, 2010; Reddy, 2010). Fostered by parents' sensitivity, infants show a preference for temporal contingencies within the first 2 months of life (Reddy, 2010). Between 3 and 5 months, infants begin to understand others' intentions, and this understanding becomes more sophisticated by 14 months when infants can infer the goals of interactive partners (Reddy, 2010; Tomasello et al., 2005). Effective co-regulation is supported when both partners accurately anticipate future actions and goals of the other (Fogel, 1993). Thus, social cognitive developments, such as intentional understanding, allow infants to actively co-regulate interactions with their mothers.

Child characteristics interact with parent characteristics and parenting approaches to influence how they interact and respond to each other. For example, research has consistently shown that child temperament – the general style with which people interact with their worlds – predicts parenting behaviors (Kiff et al., 2011; Sanson et al., 2004). In a study that examined parent-child relationships in middle childhood, child irritability led to more inconsistent discipline, while positive emotionality in children predicted greater maternal acceptance (Lengua & Kovacs, 2005). Likewise, maternal factors also play a role in the development of co-regulated social interactions. Sensitive caregiving provides the first experience of co-regulation for infants (Fogel, 1993). During this process, infants understand that their social cues, such as crying, impact the behaviors of others, and this serves as a starting point for co-regulation (Bronson, 2000). Maternal sensitivity has also been consistently correlated with children's emotion regulation, sense of self, social engagements, social-cognitive skill development, social competence, and language development (Harel et al., 2002; Howes & Hong, 2008; Licata et al., 2013; Little & Carter, 2005; Moreno et al., 2008).

Risk factors and their association with social interactions

A vast number of studies to date have highlighted the association between various risk factors, including medical risk, socio-economic disadvantage, and psycho-social concerns, and difficulties in parent-child interactions and relationships (Doiron & Stack, 2017; McQuillan et al., 2019; McQuillan & Bates, 2017; Lange et al., 2019; Treyvaud, 2014; Fonseca et al., 2020). These associations can largely be interpreted using Sameroff's (2009) theory of transactional influences and stress occurring between parents, children, and their environments. Understanding these transactions between risk factors and co-regulation requires the inclusion of various at-risk mother-infant dyads, such as medically and psycho-socially at-risk families.

In 2020 alone, over 28,000 infants were born prematurely in Canada (less than 37 weeks gestation), amounting to almost 8% of recorded births that year (Statistics Canada, 2021). Premature birth is accompanied by a host of additional stresses for infants and caregivers alike. In addition to their concerns for the wellbeing of their premature infants, parents have described their experiences in the neonatal intensive care units (NICU's) as chaotic and overwhelming, and that it felt fearful and was difficult to bond with their infants (Gonçalves et al., 2020; Hagen et al., 2016). These stresses and obstacles to fostering healthy relationships, follow mother-infant dyads beyond their NICU stays. Forcada-Guex and colleagues (2011) found that mothers of premature infants, specifically those suffering from symptoms of post-traumatic stress following their birthing experience, engaged in a more controlling manner with their infants than mothers of full-term infants. This finding has been replicated in numerous studies comparing interactive behaviors of mothers of preterm and full-term infants, with mothers showing lower levels of sensitivity and higher levels of intrusiveness with their preterm infants (Ionio et al., 2017; Muller-Nix, et al., 2004). Likewise, very low birthweight (VLBW)/preterm infants also experience unique struggles impacting them and their interactions with others. Research to date suggests that VLW/preterm infants engage in less effective emotion regulation strategies (Yaari et al., 2018), show less self-regulation (Jean & Stack, 2012), and as a result, are more difficult to soothe (Muller-Nix et al., 2004), with these challenges extending well into childhood (Dimitrova et al., 2018). Although research on co-regulation, specifically, is limited in this medically at-risk population, studies to date have identified differences from their full-term counterparts during infancy, most notably that VLBW/preterm infants engage in more unilateral and less symmetrical interactions with their mothers (Sansavini et al., 2015) and appear more reactive and brief in their symmetrical interactions (Doiron & Stack, 2017). However, it is unclear how co-

regulative differences in VLBW/preterm dyads play out in the long-term outcomes beyond infancy.

Broader socio-economic and psycho-social risk factors also intertwine with parent-infant interactions. Risk factors such as poverty, neighborhood disadvantage, fewer years of maternal education, poor parent mental health, parents' own adverse childhood experiences, and few social supports have repeatedly been associated with poorer outcomes in children, parents, and their relationships (e.g., McQuillan & Bates, 2017; Lange et al., 2019; Steele et al., 2016; Edwards & Hans, 2015; Padilla et al., 2020; Ierardi et al., 2019; Mills et al., 2012). For example, Stack et al. (2012) found that mothers recruited from disadvantaged neighborhoods and who had higher levels of childhood aggression and social withdrawal showed greater hostility and less sensitivity towards their own preschool-aged children. In turn, their children were less responsive during interactions with their mothers (Stack et al., 2012). Furthermore, Schneider and Schenck-Fontaine (2022) found that lower SES and perceived social support were associated with a more authoritarian parenting style, characterized by a focus on compliance from children and strict forms of discipline, which may include corporal punishment. Authoritarian parenting has been associated with internalizing and externalizing symptoms in youth, such as poor self-esteem and increased risk for conduct problems (Raboteg-Saric & Sakic, 2014; Thompson et al., 2003). Furthermore, there is increasing evidence suggesting that these impacts cascade through development and across generations (e.g., Stack et al., 2017; Schoon & Melis, 2019).

While medical risks, such as VLBW/preterm births, and psycho-social risks come with unique challenges and outcomes for parents, children, and their relationships, both risks are accompanied by significant levels of parenting stress. Parents of VLBW/preterm infants report unique parenting stresses associated with their infants' medical risks (Treyvaud, 2014).

Similarly, psycho-socially disadvantaged families report a range of stresses related to parenting (Lange et al., 2019). Parenting stress encompasses parents' perceptions of their children, themselves as parents, and their relationship with their children (Abidin, 1995). Similar to other risk factors, parenting stress has consistently been associated with adverse outcomes in families. The limited research to date on co-regulation and parenting stress has indicated that higher levels of parenting stress in mothers is associated with more time spent in disruptive patterns of co-regulation with their infants, meaning that members of the dyad misinterpret social cues, resulting in emotion dysregulation (Doiron & Stack, 2017). Unsurprisingly, less parenting stress has been associated with more feelings of pleasure in parents and greater use of positive parenting strategies (Crnic et al., 2005). Parenting stress also shows direct effects on children's externalizing behaviors and delays in socio-emotional development, which further affect parenting (Huang et al., 2015; Mackler et al., 2015). Parenting stress is an indicator of both the parent-child relationship and the environment (Abidin, 1995), thus making it an important variable in parent-child interactions and crucial to better understanding co-regulation in at-risk groups. It helps us to understand how co-regulation develops over time and how risk factors and co-regulation, together, are associated with child outcomes.

Taken together, risk and its associated stress on families impact the ways family members interact (notably between caregivers and their children). Caregiver-child interactions are crucial to children's developing emotion regulation and healthy understanding of social interactions (Bronson, 2000). Given that many forms of psychopathology are characterized by deficits in emotion regulation and interpersonal difficulties (Beauchaine & Cicchetti, 2019; McEvoy et al., 2013), understanding how co-regulation develops and interacts with risk factors may further enlighten our understanding of mental health difficulties. For example, researchers in the field of

trauma have found that inconsistent and neglectful caregiving creates confusion in the developing regulatory systems in children and their expectations for relationships (Hambrick et al., 2019). These sensitized systems go on to impact children in a myriad of ways throughout their development, often manifesting in emotion dysregulation. Over time, that emotion dysregulation may develop into externalizing problems, such as disruptive behaviors, and internalizing problems, such as symptoms of anxiety and depression (Winston & Chicot, 2016). Unfortunately, these symptoms further negatively impact social interactions and interpersonal relationships (Laceulle et al., 2017). Interestingly, research has also shown that relationships are crucial to mending these disrupted systems, via warm, reciprocal, and attuned interactions (Toth & Manly, 2019). Thus, understanding the trajectories in the development of co-regulation and associated factors may have important implications for both understanding the early development of psychopathologies, as well as ways to address them.

Limitations of the current literature

While advances have been made in our understanding of co-regulation in social interactions, the current literature has a number of limitations. To date, most researchers have studied interactions using discrete behaviors of interacting partners, such as gaze, vocalization, or body movements. However, even short social interactions are complex and characterized by ongoing influences between partners (Fogel, 1993). Furthermore, social interactions are shaped by partners' histories of interactions and anticipation of future interactions, which are difficult to capture using discrete behaviors (Fogel, 1993). Therefore, although discrete behaviors shape interactions, and are thus important, interactive behaviors may be better understood as general patterns. A coding system that uses behaviors as indicators of larger interactive patterns may better and more comprehensively capture the nuances and complexities of social interactions.

In addition, by examining specific developments in children's cognition, language, and motor skills, we understand more about how children help or hinder social interactions (Bornstein & Tamis-LeMonda, 2010). Likewise, maternal characteristics, such as warmth, sensitivity, and responsivity influence interactions with their children and contribute to later interaction patterns their children have with others (Biringen et al., 2014). However, while transactional influences are largely acknowledged, few studies have examined the interaction as the unit of analysis (for exceptions, see Aureli & Presaghi, 2010, Evans & Porter, 2009, Hsu & Fogel, 2003, and Feldman, 2003). Unfortunately, focusing on interactive partners in isolation, overlooks the continuous bidirectional influences taking place between partners, and ignores the impact of past behaviors on future interactive behaviors (Fogel, 1993). To fully understand the interaction between mother and child, their behaviors must be assessed together.

The current literature examines co-regulation at one point in time, most commonly during infancy (Feldman, 2003; Hsu & Fogel, 2003). While static measures of co-regulation are important for early research, co-regulation is dynamic, and is likely to change over time as relationships unfold, children mature, parents adapt, and circumstances change. Within the first 2 years, co-regulation changes substantially, with dyads becoming increasingly symmetrical over time (Aureli & Presaghi, 2010). However, despite major transitions happening in later years, such as children entering daycare and starting formal school, no studies known to the authors have investigated longitudinal trends nor outcomes in mother-child co-regulation beyond the first 2 years of life. Furthermore, little is known about how co-regulation interacts with other factors in the parent-child relationship and beyond to predict child outcomes.

Finally, the literature has largely overlooked the influence of risk status on co-regulation. Among other variables, socioeconomic status, parenting stress, medical status, and parent

psycho-social risk directly and indirectly affect the mother-child relationship (Dodge et al., 1994; Lengua & Kovacs, 2005; Muller-Nix et al., 2004), yet few (see Doiron & Stack, 2017 and Sansavini et al., 2015 for exceptions to studies on medical risk) have been studied in the context of co-regulation and none have examined it longitudinally throughout childhood. Given the demonstrated impact of risk factors on maternal, child, and relationship variables, incorporating measures of risk into studies of co-regulation is a crucial next step.

Current studies

The current studies sought to overcome the limitations described above through the following: (1) using a dynamic observational coding system, the *Revised Relational Coding Scheme* (Fogel et al., 2003), that assesses the dyad as a whole, and accounts for mutually influenced maternal and child interactive behaviors; (2) examining co-regulation longitudinally to further understand its development over time; (3) including two risk groups to understand the impact of context on co-regulation; (4) incorporating measures of parenting stress to explore its relationship with co-regulation; (5) exploring how co-regulation and risk factors interact to predict child mental health outcomes.

The overall aim of the current studies was to better understand the development and outcomes of co-regulation in typical and more at-risk contexts. The objectives were to identify and examine: (1) differences in co-regulation among low- and at-risk infant-mother dyads, (2) changes in co-regulation over time, (3) associations between infant-mother co-regulation and parenting stress in these low- and at-risk groups over time, (4) how co-regulation interacts with parenting stress to predict child mental health outcomes (i.e., symptoms of internalizing and externalizing problems) in low- and at-risk preschool-aged children, and (5) how this same interaction predicts at-risk child mental health outcomes (i.e., symptoms of internalizing and

externalizing problems) in middle childhood. Study 1 addressed objectives 1 to 3, and Study 2 addressed objectives 4 to 5.

The sample for Study 1 consisted of 3 groups of mother-infant dyads and included infants born full-term, infants born VLBW/preterm, and infants born into psycho-socially at-risk families. The latter group was part of the larger Concordia Longitudinal Research Project (Concordia Project) which recruited children between 1976 and 1978 from schools serving low socioeconomic status neighborhoods in Montreal, Quebec, Canada. These children were followed by the Concordia Project into adulthood and, subsequently, parenthood. The mothers in the present study were the original children recruited by the Concordia Project. All low- and at-risk dyads were followed across 4 time points based on the infants' ages: 6-, 12-, 18-, and 48-months. At each time point dyads engaged in a free play task that was observationally coded for patterns of co-regulation (see above for a detailed overview of these patterns). Group differences in time spent in each pattern of co-regulation were identified using MANOVAs (objective 1) and multi-level modelling was used to assess changes in co-regulation over time (objective 2) and its association with parenting stress (objective 3). It was hypothesized that low-risk dyads would engage in more symmetrical and less asymmetrical and unilateral patterns of co-regulation than the at-risk groups. Given increasing social-cognitive capacities of children (Reddy, 2010), it was also hypothesized that dyads in all groups would spend increasingly more time in symmetrical and less time in asymmetrical and unilateral patterns of co-regulation over time. Parenting stress was expected to be associated with less symmetrical co-regulation and more asymmetrical, unilateral, unengaged and disruptive forms of co-regulation. The findings from Study 1 provided a foundation for our understanding of the development of co-regulation, by exploring how it

changes both throughout and after infancy. Furthermore, it allowed us to identify whether and how parenting stress and risk impacted the trajectories of co-regulation.

Informed by the findings on co-regulation and risk in Study 1, Study 2 also incorporated the full-term low-risk dyads and the psychosocially at-risk and VLBW/preterm dyads when children were 48-months old. Their free play interactions were coded for co-regulation and further information on demographics, parenting stress, and child internalizing and externalizing symptoms were collected via mother-completed questionnaires. These questionnaires were collected in all groups when children were 4-years old and again in the psycho-socially at-risk group when children were 7-years old. Moderation analyses were conducted to determine how different patterns of co-regulation interacted with parenting stress to predict child mental health outcomes at 4-years in each group (objective 4). They were also conducted, more specifically, in the psycho-socially at-risk group to explore the longitudinal effect of the interaction between co-regulation and parenting stress at 4-years to child mental health outcomes at 7-years (objective 5). It was hypothesized that co-regulation characterized by reciprocity and engagement would show a protective moderating effect on the association between parenting stress and child mental health, in all groups, but most notably in the at-risk groups. The opposite was expected to occur for less engaged and less reciprocal forms of co-regulation (i.e., these forms were expected to exacerbate the association between parenting stress and child mental health). We expected a similar pattern of results in the longitudinal analyses for the psycho-socially at-risk group. The findings from Study 2 underscored why studying mother-child co-regulation is so crucial, particularly in the context of risky circumstances by focusing on child outcomes.

Essentially, Study 1 asked the general question of *how* co-regulation develops in infancy and early childhood, while Study 2 took our understanding further to ask the question of *what*

impact co-regulation may have on children, specifically their mental health outcomes. That is, Study 1 provided a foundational understanding of co-regulation, while Study 2 highlighted the implications of co-regulation for children. Relationships form through a series of ongoing interactions (Bronson, 2000; Fogel, 1993). While far from the only factor, caregiver-infant (and later, child) interactions form a foundation from which children develop important regulative capabilities, including emotional and behavioral regulation, and expectations for future interactions (Bronson, 2000). Previous research has long indicated that this happens through warm, sensitive, and consistent caregiving (Bronson, 2000). The dissertation research explored this further by adopting a Dynamic Systems lens that considers both mother and child factors in the development and implications of co-regulation. In doing so, our findings shed light on ways to foster and maintain healthy mother-child relationships in both low- and at-risk families.

Chapter 2: Dissertation Study 1

Co-Regulation and Parenting Stress Over Time in Full-Term, Very Low Birthweight Preterm, and Psycho-Socially At-Risk Infant-Mother Dyads: Implications for Fostering the Development of Healthy Relationships

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Manuscript published in the *Infant Behavior and Development* journal:

Doiron, K. M., Stack, D. M., Dickson, D. J., Bouchard, S., & Serbin, L. A. (2022). Co-regulation and parenting stress over time in full-term, very low birthweight preterm, and psycho-socially at-risk infant-mother dyads: Implications for fostering the development of healthy relationships. *Infant Behavior and Development, 68,* 101731. https://dx.doi.org/10.1016/j.infbeh.2022.101731

Acknowledgements: This research was financially supported in part by grants from the Social Sciences and Humanities Research Council of Canada (SSHRC), Fonds de recherche du Québecois – Société et culture (FRQ – SC), Centre for Research in Human Development (CRDH), and Concordia University awarded to Dale M. Stack (PI) and co-investigators, and graduate student fellowships awarded to Kelly Doiron from SSHRC and Concordia University. The authors gratefully acknowledge Sarah Al-Kawas, Priya Bhatia, and Nina Rufié for assistance with some of the coding, Victoria Lane and Laurie Houle for help with manuscript preparation, as well as the research teams involved in the data collection phases. We would also like to thank Claude Senneville, Nadine Girouard, Shaneha Patel, Joelle Belisle-Cuillerier, and Catherine Delisle and other members of our research team over the years for their assistance at various points with data management and collection. The Concordia Longitudinal Research Project originated in 1976 under the direction of Jane Ledingham and Alex E. Schwartzman. The project is currently directed by Lisa A. Serbin and Dale M. Stack. Gratitude is extended to the teaching hospital staff. Finally, we are most indebted to the families who participated in this study. The authors attest that there is no conflict of interest in the conduct or reporting of the current research.

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Abstract

From birth, mothers and infants co-regulate their interactions that are shaped by their socio-emotional development, relationship history, current circumstances, and goals. However, few studies have longitudinally explored co-regulation in the context of medical and psycho-social risk. The present 4-wave longitudinal study sought to shed light on factors associated with co-regulation over time in infants from 6- to 48-months. The objectives were to (1) identify differences in co-regulation among low- and at-risk infant-mother dyads, (2) explore changes in co-regulation over time, and (3) explore the associations between infant-mother co-regulation and parenting stress in these low- and at-risk groups over time. Participants included three groups of infant-mother dyads (full-term [FT], $n = 47$; very low birthweight/preterm [VLBW/preterm] born 26-32 weeks, weighing 800-1500g, $n = 62$; psycho-socially at-risk where parents had histories of socioeconomic disadvantage, $n = 56$) followed longitudinally at 6-, 12-, 18-, and 48-months of age. Dyads engaged in a free play in their homes that was coded for co-regulation using Fogel and colleagues' (2003) *Revised Relational Coding System* (*RRCS*), and mothers reported on their level of parenting stress. Results from MANOVAs at each time point indicated significant differences between the groups at 18-months, with psycho-socially at-risk dyads engaging in more one-sided interactions than FT and VLBW/preterm dyads, and more dysregulation and miscommunication than VLBW/preterm dyads. Multi-level models of co-regulation revealed that dyads became progressively less synchronous from 6- to 12-months, followed by greater synchrony and mutual reciprocity from 12-months onwards. Parenting stress was associated with less synchrony and less mutual reciprocity amongst the at-risk groups. Maternal education was associated with greater engagement and girls tended to engage in more synchronous interactions than boys. Our results underscore the value and implications of

considering background risk and concurrent parent perceptions in the development and reciprocity of parent-infant co-regulation and their subsequent relationships from infancy onwards.

Keywords: co-regulation, infancy, risk, parenting stress, VLBW/preterm, psycho-social risk, longitudinal

Co-Regulation and Parenting Stress Over Time in Full-Term, Very Low Birthweight Preterm, and Psycho-Socially At-Risk Infant-Mother Dyads: Implications for Fostering the Development of Healthy Relationships

From birth, infants are immersed into a social world comprised of social interactions and exchanges with caregivers and extended family. For most infants, early social interactions occur predominantly with their parents or primary caregivers and serve as a foundation for infants' social, emotional, and cognitive development. It is now commonly accepted that these interactions are transactional, meaning they are influenced by a wide range of factors, including parent characteristics, infant characteristics, and broader contextual factors that bi-directionally influence each other (Sameroff, 2009). Risk factors such as medical concerns (e.g., very low birthweight [VLBW]/preterm births; Muller-Nix et al., 2004), maternal mental health (Hakanen et al., 2019), and disadvantaged backgrounds (Stack et al., 2012) are associated with more maladaptive parenting styles and poorer developmental outcomes in children. Yet little is known about how these risky contextual factors impact how mothers and infants jointly initiate, regulate, and maintain their interactions (see Doiron & Stack, 2017 and Sansavini et al., 2015 for some exceptions).

In his description of mother-infant interactions from a Dynamic Systems perspective, Fogel (1993) purports that mother-infant interactions are shaped by the dyad's history, experience, and expectations in an ongoing and dynamic manner. When dyads do this, they are co-regulating their communication. According to Fogel (1993), this co-regulative process cannot be broken down into discrete parts without losing the essence of their interaction. Thus, the dyad's interaction itself must be analyzed, as it is a joint, reciprocal, and synchronous venture between mothers, infants, and broader contextual factors (Fogel, 1993), one that is important in

shaping infant development. Given the wealth of research highlighting the negative impacts of risky contexts on maternal and child characteristics, it is important to more closely examine how these factors play a role in mother-infant co-regulation and its development.

Co-Regulation

Optimal co-regulation of communication occurs when the goals and expectations of the mother-infant dyad remain synchronous (Fogel, 1993). It allows for open and reciprocal communication of thoughts, feelings, and goals, with each partner adjusting their behavior in coordination with the other. According to Hsu and Fogel (2003), co-regulation is categorized into three patterns. *Symmetrical* co-regulation describes interactions when mother and child are engaged with each other and contribute to the ongoing interactions through various forms of body language, eye contact, and vocalizations. Symmetrical interactions are characterized by mutual synchrony and reciprocity between the infant and mother as they work towards a common communicative goal by adjusting their approach based on each other's social cues (Provenzi et al., 2018). This occurs through attunement to each other's emotions and responding contingently and sensitively to expressed wants and needs (Beebe et al., 2016; Fogel, 1993; Hsu & Fogel, 2003; Provenzi et al., 2018). When both mother and child are engaged but only one contributes to the interaction, the co-regulation is considered *asymmetrical*. Dyads engage in *unilateral* co-regulation when one person ignores the other's bids for attention, engaging instead in their own activity. Both asymmetrical and unilateral patterns of co-regulation describe asynchronous interactions between the mother and infant. Co-regulation is absent in *unengaged* (when neither mother nor child is engaged) and *disrupted* (when there is a miscommunication leading to emotional dysregulation such as crying) interactions (Fogel et al., 2003). In accordance with the dynamic systems approach, dyads shift between different patterns of co-

regulation throughout their interactions, falling in and out of synchrony from moment to moment.

Research on the development of co-regulation is limited, with no studies extending beyond the second year of life. Those that have explored early development of co-regulation have noted important socio-emotional implications of specific patterns for infant development, and for the mother-infant relationship. For example, Evans and Porter (2009) reported that infants who engaged actively with their mothers (i.e., more symmetrical interactions) at 6-months of age showed greater psychomotor and mental development at 9-months and were more securely attached to their mothers at 12-months. Conversely, those who ignored their mother's bids for interactions (i.e., more unilateral co-regulation) at 6-months showed weaker mental development at 9-months and more insecure attachment patterns at 12-months (Evans & Porter, 2009). Doiron and Stack (2017) also found co-regulation to be associated with the mother-child relationship at 6-months of age. Specifically, higher levels of infant responsiveness were associated with greater time spent in symmetrical co-regulation and less time spent in unilateral co-regulation (Doiron & Stack, 2017).

Of the few studies that have examined co-regulation longitudinally, results have consistently shown that typically-developing infant-mother dyads engage in more symmetrical co-regulation over the first two years of life (Aureli & Presaghi, 2010; Evans & Porter, 2009). More specifically, in their bi-weekly observations conducted when infants were 10- to 24-months-old, Aureli and Presaghi (2010) found that time spent in symmetrical co-regulation followed a positive linear trend over time, while time spent in unilateral co-regulation followed a negative linear trend. Although dyads initially engaged in predominantly unilateral interactions, they engaged in predominantly symmetrical interactions by the end of their second year (Aureli

& Presaghi, 2010). These developments in co-regulation coincide with significant cognitive, social, and self-regulation developments during infancy. That being said, little is known about how these trajectories of co-regulation extend into the first three years and how key environmental factors and adversity may influence this development. Furthermore, examining outcomes in the preschool period creates a better understanding of the implications of co-regulation during infancy. Taking a long-term approach to studying co-regulation is crucial because co-regulation is an ongoing, dynamic process that is shaped by the dyad's history of sensitivity and mutual reciprocity (Fogel, 1993).

Mother-Infant Interactions in Adverse Contexts

Raising an infant under adverse circumstances, including medical, socio-economic, or psycho-social, is a difficult and stressful endeavour that impacts maternal and infant wellbeing, as well as their interactions. Høifødt et al. (2020) found that mothers who reported greater parenting stress struggled to read and respond to their infants' social cues more than those with lower parenting stress. Similar findings were observed by Doiron and Stack (2017), who found that higher parenting stress was associated with more time spent in disrupted co-regulation (i.e., dyads were misinterpreting social cues and becoming dysregulated) at 6-months. Furthermore, mothers with greater symptoms of depression and anxiety showed less sensitivity to their 3-month-old infants (Ierardi et al., 2019). Maternal stress also affects infant development. In a systematic review of the literature, Oyetunji and Chandra (2020) found that greater postpartum stress was associated with poor language and cognitive development among infants. These are crucial skills required for co-regulation (Provenzi et al., 2018). Importantly, a key element of co-regulation, maternal sensitivity (or insightfulness), was shown to be protective against the impact

of stress on mother-infant interactions, whereby mothers with greater insightfulness engaged in more positive parenting with their infants (Martinez-Torteya et al., 2018).

To date, most research into the association between risk factors and co-regulation has focused on medical risk, specifically, very low birthweight (VLBW)/preterm infant-mother dyads (Doiron & Stack, 2017; Sansavini et al., 2015). Mothers of preterm infants display significantly higher levels of distress, anxiety and negative feelings relative to mothers of full-term infants (Gonçalves et al., 2020; Treyvaud et al., 2011, 2014; Trumello et al., 2018). Differences are also observed on the dyadic level in co-regulation. In their study on extremely low gestational age (ELGA) infant-mother dyads, Sansavini et al. (2015) found that ELGA infants engaged in less symmetrical and more unilateral co-regulation with their mothers than their full-term counterparts at 12-months of age. These co-regulative differences align with past research showing that mothers interact more intrusively with, and show less sensitivity to, preterm infants than full-term infants (Muller-Nix et al., 2004; Ionio et al., 2017). Importantly, maternal sensitivity serves as a protective factor against long-term internalizing symptoms in youth born preterm (Faure et al., 2017). Given that preterm infants often go on to develop more emotional difficulties than their full-term counterparts throughout infancy (Muller-Nix et al., 2004) and childhood (Dimitrova et al., 2018), understanding the protective features of adaptive mother-infant interactions is imperative.

Interestingly, the aforementioned co-regulative differences were not observed at 6-months of age when Doiron and Stack (2017) compared full-term to healthy VLBW/preterm infant-mother dyads, whose ages were corrected for prematurity. However, the nature of the symmetrical interactions still differed between the groups. Full-term dyads engaged in more sequential forms of symmetrical co-regulation, characterized by back-and-forth exchanges, while

VLBW/preterm dyads engaged in more spontaneous shows of mutual emotion (also a form of symmetrical co-regulation; Doiron & Stack, 2017).

Dynamic Systems Theory emphasizes that interactions are a joint venture, influenced by mother and infant (Fogel, 1993). Research supports this mutual influence and the importance of considering preterm infant behaviors and abilities in managing interactions with their mothers. Yaari et al. (2018) found that preterm infants showed poor emotion regulation skills at 4-months of age, as indicated by less positive affect and more gaze aversion than their full-term counterparts when their mothers were emotionally unavailable. Jean and Stack (2012) also found that 5-month-old VLBW/preterms engaged in less self-regulatory than full-terms in similar circumstances. Preterm infants have also been shown to exhibit more negative emotionality, making them more difficult for parents to soothe (Muller-Nix et al., 2004). It is likely that these differences in interactive behaviors of both mother and infant occurring in the context of a stressful medical environment contribute to the early differences in patterns of co-regulation observed by Sansavini et al. (2015).

Another risk factor that has been associated with mother-infant interactions is parent histories of psycho-social risk. Research has repeatedly described psycho-social risk as intergenerational with cascading effects on socio-emotional development (Stack et al., 2017). In their intergenerational longitudinal study, Schoon and Melis (2019) found that offspring of parents in the high-risk group (i.e., low socio-economic status, single-parent families, unemployment, lower parent education, depression, and physical illness) were more likely to be considered high-risk in adulthood. Intergenerational studies have also highlighted the differences in the quality of relationships between high-risk mothers and their children. In their study of mothers with childhood histories of disadvantage, Stack et al. (2012) found that mothers with

childhood histories of aggression and social withdrawal displayed higher levels of hostility towards their children. In turn, their children showed lower levels of responsiveness towards their mothers, suggesting a reciprocal pattern of risky interactions (Stack et al., 2012). The difficulties disadvantaged mothers face in responding sensitively and reciprocally to their infants is in part posited to be accounted for by lower neural sensitivity in the amygdala to their infants' negative emotional expressions (Kim et al., 2017). These interactive differences among at-risk dyads have significant implications that continue throughout development. In another longitudinal study, direct associations were found between children's internalizing symptoms and negative parenting styles and maternal emotionality, as well as socio-economic disadvantage (Mills et al., 2012). These findings suggest that a reciprocal pattern of risk occurs in the context of dyadic mother-child interactions and point to the need for a deeper understanding of its continuity and the role of psycho-social risk in co-regulation.

The Present Study

The present study was designed to extend previous findings in several ways and to fill some gaps in infant-mother co-regulation from a Dynamic Systems perspective by exploring its development longitudinally in 4 waves from 6- to 48-months of age. In order to enhance the generalizability of the findings, free play interactions took place in the naturalistic setting of the dyads' homes. The free play procedure allowed dyads the flexibility to engage in both dyadic and triadic (including toys) interactions, which elicit different patterns of co-regulation (Aureli et al., 2018). In accordance with the Dynamic Systems perspective, patterns in the dyads' communication were observed and analyzed using Hsu and Fogel's (2003) patterns of co-regulation, rather than separate discrete behaviors of the mother and infant (Fogel et al., 2003). A wealth of research has demonstrated support for the transactional associations between

environment, parenting, and infant-mother relationships (Sameroff, 2009). Examining risk factors, including medical and psycho-social risk, provides insight into the interplay between mothers, infants, and their broader environments. Thus, in addition to low-risk dyads, whose infants were born full-term, we included two additional groups: those who were medically at-risk, with infants born VLBW/preterm, and a psycho-socially at-risk group whose mothers had histories of disadvantage. Finally, given the demonstrated impact of parenting stress in mother-infant relationships (Doiron & Stack, 2017; Ierardi et al., 2019; Kim et al., 2017; Mills et al., 2012), we examined how parenting stress was associated with co-regulation over time in each of the three groups of mother-infant dyads.

In this 4-wave longitudinal design in a Canadian sample, the objectives were to (1) identify differences in co-regulation among low- and at-risk infant-mother dyads, (2) examine patterns of change in co-regulation over time, and (3) examine associations between infant-mother co-regulation and parenting stress in these low- and at-risk groups over time. It was hypothesized that full-term dyads would engage in more symmetrical co-regulation and less asymmetrical and unilateral co-regulation than their VLBW/preterm and psycho-socially at-risk counterparts. VLBW/preterm and psycho-socially at-risk dyads were expected to show more instances of non-co-regulation (i.e., unengaged and disrupted patterns). It was also hypothesized that all groups would engage in more symmetrical and less unilateral and asymmetrical co-regulation over time. Finally, higher levels of parenting stress were expected to be associated with less symmetrical co-regulation and more asynchronous forms of co-regulation (i.e., asymmetrical, unilateral, unengaged, and disruption).

Methods

Participants

The sample consisted of 165 infant-mother dyads who were observed longitudinally when infants were 6-, 12-, 18-, and 48-months old. The dyads fell into three groups: infants who were born full-term, those who were born VLBW/preterm, and those with family histories of psycho-social risk. The full-term and VLBW/preterm groups were recruited from the same large teaching hospital in Montréal, Canada. They were matched for infant age, sex, and maternal education. The psycho-socially at-risk dyads were part of a larger prospective intergenerational longitudinal study (see Psycho-Socially At-Risk section below). The participants communicated in either English or French.

Full-Term

Forty-eight healthy, full-term infants born between 37- and 41-weeks gestation (M = 39.54, SD = 1.11) with a birthweight greater than 2,500 grams (M = 3504.15, SD = 434.69) participated in the study with their mothers. They were recruited through birth records from the teaching hospital. Mothers were provided with a letter outlining the study and contacted by telephone before voluntarily participating. The infants included 22 males and 26 females. The majority of the infants were first-born (62.50%). Twenty-five percent of the infants had one older sibling, while 12.60% had multiple older siblings. Caregivers generally used a mix of bottle- and breast-feeding (41.67%) followed by exclusive breast-feeding (35.42%), and bottle-feeding (22.92%). The mean age of mothers at the time of birth was 30.23 years (SD = 5.01). Mothers predominantly identified their ethnic origin as White (89.60%) along with some mothers identifying as Black (2.10%), Asian (4.20%), and Hispanic (4.20%). They had a mean of 14.52 (SD = 2.06) years of education and the mean occupational prestige scores corresponded to occupations such as general managers of small enterprises and client information clerks. Over the course of the infant's first 4 years, approximately 15% of their parents had separated or

divorced, and 75% of infants continued to live in two-parent households. The relationship status of parents of the remaining 10% of infants was not reported, and therefore, unknown.

VLBW/Preterm

Sixty-one VLBW/preterm infants born between 24- and 33-weeks gestation (M = 28.49, SD = 2.28) with a birthweight under 1,500 grams (M = 1081.84, SD = 248.04) participated in the study with their mothers. In collaboration with the chief neonatologist and the VLBW follow-up clinic, dyads were recruited from the same teaching hospital as the full-term dyads. Dyads who met the inclusion criteria (i.e., were healthy, living with their biological mothers, and fit the gestation and weight criteria for VLBW) were given a letter outlining the study and contacted over telephone by the follow-up clinic Nurse to voluntarily participate in the study. Infants who experienced serious medical issues (e.g., congenital health problems), or mothers who had an increased risk of psycho-social problems were excluded from the study. Thus, the final sample included infants that were relatively healthy, aside from their VLBW/preterm status. That said, because of their VLBW/preterm status, infants had spent time in the neonatal intensive care unit (NICU), where parents were able to visit. To ensure accurate comparisons to the full-term and psycho-socially at-risk groups, the ages of VLBW/preterm infants were corrected for prematurity by subtracting the number of weeks infants were premature from their postnatal ages. The infants included 32 males and 29 females. Majority were first-born (47.50%), followed by second-born (27.90%), and third-born (16.40%). Approximately 8% of the VLBW/preterm infants had more than two siblings. Caregivers predominantly used a combination of breast- and bottle-feeding (44.26%) or bottle-fed (42.62%). A smaller group exclusively breast-fed (11.48%). The mean age of mothers at the time of birth was 32.51 (SD = 5.56). They identified their ethnic origins as White (54.10%), Black (23.00%), Hispanic (11.50%), Middle Eastern (6.60%), and Asian

(4.90%). Mothers had a mean of 13.00 years of education (*SD* = 2.11) and the mean occupational prestige scores corresponded to occupations such as nursing associates and insurance representatives. Over the course of the infants' first 4 years, approximately 20% of their parents separated or divorced (13% of the families separated within the first 6 months of the infants' birth). The other 80% of infants continued to live in two-parent households.

Psycho-Socially At-Risk

Fifty-four infants with family histories of psycho-social risk also participated in the study with their mothers. They were born between 37- and 43-weeks gestation (*M* = 39.72, *SD* = 1.47) and with a birthweight ranging between 2,225 and 4,773 grams (*M* = 3423.76, *SD* = 501.99). This subsample was part of the larger, ongoing prospective, longitudinal, and intergenerational study that recruited children in grades 1, 4, and 7 from schools serving disadvantaged neighborhoods in Montréal Canada between 1976-1978 (Concordia Longitudinal Research Project). These children were followed into adolescence, adulthood, and parenthood. The mothers in the present study are a subsample of the original participants in the Concordia Project. For a more detailed description of the Concordia Project sample, see Schwartzman et al. (1985), Serbin et al., (1998) and Stack et al. (2017). The mean age of mothers at the time of birth was 29.16 (*SD* = 3.34). All mothers in the present study identified their ethnic origin as White and had mean of 12.94 years of education (*SD* = 2.09) and the mean occupational prestige scores corresponded to occupations such as printing and trade workers. The infants in the present study included 23 males and 33 females. Half of the infants were first-born (50.00%), followed by second-born (35.20%). Approximately 15% of the infants had 2-3 siblings. Caregivers used a combination of bottle- and breast feeding (46.30%), exclusive bottle-feeding (42.59%), or exclusive breast-feeding (11.11%). Approximately 13% of the infants' parents separated or

divorced within the infants' first four years. The other 87% of infants remained in two-parent households, with one family also living with one grandparent.

Procedure

Dyads were visited in their homes at four time points when infants were approximately 6-, 12-, 18-, and 48-months old. During each visit, researchers explained the study and procedure and obtained informed consent from the mothers. Mothers determined the timing of the visits to account for infants' naps and feeding times and to ensure they were alert. They completed questionnaires, took part in interviews, and engaged in free play interactions with their infants. During the free play task, mothers were asked to "play with [their] infant as [they] normally would" on a floormat. These interactions were videotaped for later observational coding and lasted 5 minutes at the 6-month visit and 15 minutes at the 12-, 18-, and 48-month visits. Dyads were provided with age-appropriate, standardized toys to use in a well-lit room with minimal distractions during the free play task. At the 6-month visit, the toys included three books, two puppets, large, age-appropriate blocks, and two large-pieced puzzles. At the 12-, 18-, and 48-month visit, the toys included a doll, comb, brush, tea set, telephone, Lego, and two books. Mothers were reminded that they were free to stop the procedure at any time. The procedure was stopped if the infant became upset and re-initiated only after the infant was soothed and settled ($n_{6mos} = 3$, $n_{12mos} = 3$, $n_{18mos} = 1$, $n_{48mos} = 1$). Following each visit, mothers were thanked for their participation and presented with an "Infant Scientist Award".

Measures

Questionnaire Measures

Demographic Information Questionnaire. At each visit, mothers completed the Demographic Information Questionnaire (DIQ) to collect socio-demographic information, such

as maternal level of education, family characteristics, and infant health. This measure has been used reliably to collect demographic information of participants in past studies from our laboratory (e.g., De Genna et al., 2007; Mantis et al., 2014; Briscoe et al., 2017).

Parenting Stress Index. The Parenting Stress Index, third edition (PSI-3) is a self-report measure that examines stress brought on by parenting and within the parent-child relationship. At each visit, mothers completed the short form version of the PSI-3, which consists of 36 items rated on a five-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). These items load onto three subscales: parenting distress (stress related to one's role as a parent), parent-child dysfunction (parent perceptions of problematic interactions with their children) and difficult child (parent perceptions of difficulty managing their child). These three subscales load onto the total stress score, which accounts for overall perceived parenting stress. PSI-3 scores for the present study were reverse-coded so that higher scores indicated greater distress. Previous research has indicated excellent reliability and high validity in normative samples (Abidin, 1995; Haskett et al., 2006). Internal consistencies of all subscales were calculated at each time point in our sample and ranged from .68 to .91.

Observational Measures

Co-Regulation. Patterns of co-regulation were observationally coded using the *Revised Relational Coding System* (RRCS; Fogel et al., 2003). The RRCS is unique in that it codes the dyad as a whole, rather that the individuals' discrete behaviors. The codes are informed by how each member in the dyad relate to each other through vocalizations, eye contact, movement, and body language. The RRCS is composed of five overarching patterns of co-regulation: symmetrical, asymmetrical, unilateral, disruption, and unengaged. While there are also sub-codes in the RRCS, only the overarching codes were analyzed for the current study because of low

variability within the sub-codes. A separate "No Code" was reserved for situations when one or both members of the dyad were not visible in the video (i.e., outside of the frame).

During symmetrical co-regulation, both mother and child are engaged with each other or a mutual point of interest (e.g., a toy). They each also contribute to the interaction through various forms (e.g., vocalizations, movement, or general body language) that build upon previous contributions from each partner. Members of the dyad are also engaged with each other or a mutual point of interest during asymmetrical co-regulation. However, unlike symmetrical, only one member of the dyad actively contributes to the interaction while the other passively observes. During unilateral co-regulation only one partner within the dyad is engaged, while the other is unengaged. Disruptive co-regulation occurs when there is misinterpretation or disregard for social cues that leads to emotional dysregulation (e.g., one partner cries after a toy of interest is removed from the interaction by the other partner). Unengaged patterns occur when both partners are disengaged from the interaction (i.e., they participate in independent activities and do not interact with each other). Disrupted patterns indicate the breakdown of co-regulation, while unengaged patterns indicate the absence of co-regulation.

Observational coding was completed using Mangold INTERACT 17 (2020) computer software, which allows for moment-by-moment coding of behavior. Within each interaction, the beginning and end of a pattern of co-regulation was coded. The overall durations within each pattern of co-regulation were then converted to percent-durations (i.e., percent of time spent in each pattern of co-regulation from the overall interaction). As suggested by Fogel et al. (2003), only interactive behaviors lasting two seconds or more were coded.

The primary coder was trained by establishing reliability with another coder who was trained by lab members of the coding system's developer. To ensure reliability with the primary

coder (graduate student), senior undergraduate students trained on the RRCS coded one-third of the sample, in each group at each time point. These second coders were blind to the hypotheses of the study. The kappa coefficients for reliability for each pattern of co-regulation ranged from .80 to .90.

Analysis

Data Preparation

Prior to analyses, data were screened, and assumptions were checked for multivariate analyses of variance (MANOVA) and multilevel growth modelling (MLM). To assess normality of the distribution through kurtosis and skew, descriptive statistics were run on percent-durations for each pattern of co-regulation for each group at each time point. Outliers were assessed by transforming percent-durations of patterns of co-regulation into *z*-scores. As recommended by Kline (2009), outliers were defined as being more than 3 *SD* from the mean and were converted to the next most extreme score within 3 *SD*. The data was normally distributed after outliers were converted. The co-regulation category, No Code, was removed from the analyses due to extremely low frequency (<1% of time spent during the interactions). All data cleaning was conducted using IBM SPSS Statistics (Version 27).

A series of one-way analyses of variances (ANOVAs) and post-hoc comparisons, using the Sidak correction, were conducted to assess for demographic differences between groups. As expected, VLBW/preterm infants had lower birth weight and weeks of gestation than their full-term and psycho-socially at-risk counterparts. Furthermore, mothers of VLBW/preterm infants were older than those of full-term and psycho-socially at-risk infants, while mothers of full-term infants had more years of education than those in the at-risk groups. There were no other differences.

Analytic Approach

MANOVAs were used to assess differences among groups in time spent in each pattern of co-regulation. Given the attrition over time, a separate MANOVA was conducted at each of the four time points. MANOVAs were chosen to limit the number of analyses and minimize type II error. All MANOVAs were conducted using SPSS.

Multi-level growth modelling (MLM) was used to assess the association between parenting stress and co-regulation over time in each of the three groups. This approach allowed for examination of both between- and within-dyad effects over time and is appropriate for assessing repeated measures with variability in intervals between time points (Burchinal et al., 2006). Intraclass coefficients (ICCs) were calculated for each pattern of co-regulation. These represent the within-person stability of co-regulation. Separate growth curves were first modelled for each pattern of co-regulation within each group. This included modelling the intercepts and slopes (i.e., rates of change in proportion of time spent in the different patterns of co-regulation). Four models were estimated that included (1) no change, (2) linear change, (3) quadratic change, and (4) cubic change. Given the conservative sample size, variances were constrained to increase power. PSI subscales (parent distress, parent-child dysfunction, difficult child) and total parenting stress were then entered as predictors of co-regulation. Following recommendations from Curran and Bauer (2011) for examining between-dyad effects, each PSI subscale was aggregated across all time points and entered as mean-centered time-invariant predictors. For within-dyad effects, PSI subscales were entered as person-centered, time-variant predictors. The models also included maternal education and infant sex as predictors, which have previously been associated with mother-infant interactions (Matte-Gagné et al., 2018; Else-Quest, 2012).

For all analyses, only significant results were included in the text. Trends were included if they aligned theoretically and with the hypotheses, although they were not treated as significant.

Handling of Missing Data

Missing data occurred in the study due to attrition. Approximately 31-38% of the total sample was missing at different time points throughout the study. Among full-term dyads, the rate of missing data ranged from 22.92-43.75% from T2 to T4. Among VLBW/preterm dyads it ranged from 32.79-40.98% and among psycho-socially at-risk dyads it ranged from 27.88-38.18%. Missing data was addressed through multiple imputations generated in *MPlus*. Twenty imputed datasets were generated using the Markov Chain Monte Carlo simulation. The model estimates generated in the MLM analyses used meta-analyses of results from each of the imputed datasets. Little's test was not statistically significant, $\chi^2(772) = 204.55$, $p = 1.00$, indicating that data were missing completely at random.

Results

Descriptive Statistics

Time spent in each pattern of co-regulation varied across the time points. Dyads engaged in stable patterns of unilateral and unengaged co-regulation from 12- to 18-months and disrupted co-regulation from 12- to 48-months, albeit at a low frequency. Dyads engaged in predominantly symmetrical co-regulation across all time points, followed by unilateral and asymmetrical patterns, respectively. Dyads rarely engaged in unengaged or disruptive co-regulation (< 1% of the time). In contrast, all subscales of parenting stress remained stable across all time points, most notably in the parenting distress subscale and total parenting stress scale. VLBW/preterm dyads reported the highest overall levels of parenting stress at all time points, with full-term and

psycho-socially at-risk dyads showing similar levels of parenting stress. No significant group differences were found in parenting stress. See Table 1 for means, standard deviations, and correlations of co-regulation and parenting stress over the four time points.

Objective 1: Associations Between Birth Status and Time Spent in Different Patterns of Co-Regulation

A series of three-group one-way between subjects MANOVAs were performed on five patterns of co-regulation: symmetrical, asymmetrical, unilateral, unengaged, and disruption for each time point (6-, 12-, 18-, and 48-months). The variable, birth status (full-term, VLBW/preterm, and psycho-socially at-risk dyads) was used to predict time spent in each pattern of co-regulation. A statistically significant Box's *M* test ($p < .001$) at all time points indicated unequal variance-covariances in co-regulation across birth status and thus necessitated the use of Pillai's trace in assessing the multivariate effect.

Our hypothesis was supported at 18-months, whereby time spent in different patterns of co-regulation was significantly affected by birth status, Pillai's trace = 0.15, $F(6, 224) = 3.04$, $p = .007$, 1 – Wilks' lambda = .15. Follow-up univariate ANOVAs, using a stringent alpha level of .012 revealed that time spent in asymmetrical co-regulation was associated with birth status, $F(2, 115) = 7.67$, $p < .001$, $\eta^2 = .12$. A trend was observed for the effect of birth status on disruptive co-regulation $F(2, 115) = 4.43$, $p = .014$, $\eta^2 = .073$.

As recommended by Meyers et al. (2013), Tamhane post hoc tests indicated that psycho-socially at-risk dyads spent more time in asymmetrical co-regulation ($M = 0.08$, $SD = 0.08$) than full-term ($M = 0.05$, $SD = 0.04$) and VLBW/preterm dyads ($M = 0.04$, $SD = 0.03$) when infants were 18-months old. They also suggested that psycho-socially at-risk dyads spent more time in

disruptive co-regulation (M = 0.01, SD = 0.03) than full-term dyads (M = 0.0007, SD = 0.002) at 18-months.

No statistically significant effects or trends were observed at 6-, 12-, or 48-months for the effect of birth status on co-regulation.

Objectives 2 and 3: Change in Co-Regulation Over Time and Associations Between Co-Regulation and Parenting Stress Over Time

Multi-level modelling (MLM) was conducted to first estimate the change in time spent in each of the five patterns of co-regulation over time within each group of dyads. Results of the unconditional mean models showed adequate ($p < .05$) within-person variation, or change over time, on all patterns of co-regulation. Stability of co-regulation was moderate with intraclass coefficients (ICCs) ranging from .20 to .56. Intercepts and slopes of mean-levels of co-regulation were also estimated. See Table 2 for a summary of the final MLM models for each pattern of co-regulation.

Objective 2: Change in Co-Regulation Over Time

The means of the intercepts for symmetrical co-regulation in all groups (full-term, VLBW/preterm and psycho-socially at-risk) were statistically significant ($\gamma_{00,\,20,\,40}$ = 109.28, 100.76, and 88.63, respectively). Consistent with our hypotheses, symmetrical co-regulation in full-term and VLBW/preterm dyads followed a statistically significant cubic (s-shaped) trend over time ($\gamma_{13,\,32}$ = -13.91 and -9.72), meaning that it initially decreased from 6- to 12-months, increased from 12- to 18-months, and continued to increase (to a lesser extent) from 18- to 48-months. It followed a statistically significant positive linear trend among the psycho-socially at-risk dyads from 6- to 48-months (γ_{50} = 26.07; See Figure 1).

Significant intercepts were only observed for asymmetrical co-regulation in the VLBW/preterm and psycho-socially at-risk groups ($\gamma_{20, 50}$ = -15.21 and 20.08). Within the VLBW/preterm dyads, asymmetrical co-regulation followed a statistically significant quadratic (u-shaped) rate of change over time (γ_{31} = 2.88). It initially decreased over time, reaching a low at 18-months, then gradually became increasing. Among the psycho-socially at-risk dyads, time spent in asymmetrical co-regulation followed a cubic (s-shaped) trend over time (γ_{52} = -3.67). Asymmetrical co-regulation in the psycho-socially at-risk group decreased from 6- to 12-months, then increased from 12- to 18-months, and decreased again from 18- to 48-months (See Figure 2).

A statistically significant intercept was observed for unilateral co-regulation in the full-term group (γ_{00} = -18.43). All groups (full-term, VLBW/preterm, and psycho-socially at-risk) showed statistically significant cubic (s-shaped) rates of change over time ($\gamma_{12/32/52}$ = 13.92, 7.80, and 9.70, respectively). Consistent with our hypotheses, all groups showed initially increasing unilateral co-regulation that peaked at 12-months and decreased sharply from 12- to 18-months. It continued to decrease more gradually after 18-months (See Figure 3).

A significant intercept was observed in unengaged interactions for the psycho-socially at-risk group (γ_{40} = 3.54) only. No significant intercepts or slopes were observed for disruptive co-regulation. This may have been due to the lower frequency of these forms of co-regulation.

Objective 3: Associations Between Co-Regulation and Parenting Stress Over Time

To address the third objective of the study, measures of parenting stress (taken from the PSI-3; Abidin, 1995) were added to the models predicting each pattern of co-regulation. They were added as time-variant variables when testing within-person changes over time, and as time-invariant (aggregated) variables when testing between person differences over time. Maternal

education and infant sex were also added to the model as predictors. The results of the models showed significant effects and trends at the between-dyad in the VLBW/preterm and psycho-socially at-risk groups. No significant effects were found at the within-dyad level.

At the between-level in VLBW/preterm dyads, infant girls engaged in significantly more symmetrical co-regulation with their mothers than infant boys ($\gamma_{26} = 6.84$, $p < .032$). A trend also emerged among VLBW/preterm dyads, whereby mothers with lower levels of perceived total parenting stress spent greater proportions of time in symmetrical co-regulation with their infants ($\gamma_{21} = -0.17$, $p = .097$). An additional significant effect of infant sex and parenting stress, specifically, perceived parental distress, occurred for unilateral co-regulation in VLBW/preterm dyads. Mothers of boys ($\gamma_{26} = -4.77$, $p < .034$) with higher perceived levels of parenting distress ($\gamma_{23} = 0.42$, $p < .016$) spent greater proportions of time in unilateral co-regulation. Although parenting stress was not associated with asymmetrical co-regulation in VLBW/preterm dyads, results showed that mothers with greater years of maternal education spent greater proportions of time in asymmetrical co-regulation ($\gamma_{25} = 1.19$, $p < .015$).

A between-level trend on co-regulation were also observed in the psycho-socially at-risk group. Mothers with higher perceived total parenting stress spent lower proportions of time in asymmetrical co-regulation with their infants ($\gamma_{41} = -0.08$, $p = .082$).

Discussion

In the current study we sought to examine the early development of co-regulation between mothers and their infants. The findings supported the hypotheses that time spent in different patterns of co-regulation would be associated with the dyads' exposure to medical and psycho-social risk, as well as maternal perceptions of parenting stress. Our findings highlight the

important contextual risk factors that contribute to how mothers and infants co-regulate their interactions and go beyond the first year of life.

The first objective was to investigate differences in patterns of co-regulation across low- and at-risk dyads. Our hypotheses were partially supported, with group differences emerging at 18-months of age. Although no differences in time spent in symmetrical co-regulation were found, the psycho-socially at-risk dyads engaged in more asymmetrical co-regulation at 18-months than their full-term and VLBW/preterm counterparts. Psycho-socially at-risk dyads, whose mothers attended schools serving low-income neighbourhoods, also engaged in more disrupted interactions than full-term dyads at this time. These group differences are consistent with Stack et al.'s (2012) findings that psycho-socially at-risk dyads struggled to engage in synchronized and reciprocal interactions. Instead, these mothers displayed less sensitivity and more hostility towards their children than their low-risk counterparts, who in turn were less responsive (Stack et al., 2012). Thus, while infants may remain engaged in the interaction, they may be less likely to contribute (i.e., asymmetrical) because historically, their contributions have been misread and responded to inappropriately. Furthermore, this difficult relationship history and style may lead to a frustrated and dysregulated breakdown in co-regulation (i.e., disruption).

Although also at risk, VLBW/preterm dyads did not exhibit the same co-regulative difficulties as the psycho-socially at-risk group. This is surprising, given that differences in mother-infant co-regulation and relationships have been observed in prior studies (Ionio et al., 2017; Muller-Nix et al., 2004; Sansavini et al., 2015). However, researchers have also found that cognitive development plays a mediating role in the association between birth status and mother-infant interactions (Harel-Gadassi et al., 2020). Therefore, such co-regulative differences may not have emerged in our purposely conservative and healthy sample of VLBW/preterm dyads.

This is consistent with previous studies using this sample at 6-months that found fewer differences between the full-term and conservative VLBW/preterm groups (Doiron & Stack, 2017; Jean & Stack, 2012).

The second objective was to examine changes in co-regulation from 6- to 48-months of age. Again, our hypotheses were partially supported. Full-term and VLBW/preterm dyads initially spent progressively less time in symmetrical co-regulation from 6- to 12-months, followed by a sharp increase from 12- to 18-months and a more levelled, but continuous, increase from 18- to 48-months. In contrast, the time psycho-socially at-risk dyads spent in symmetrical co-regulation steadily increased from 6- to 48-months of age. Interestingly, all three groups followed the opposite trend from 6- to 48-months for time spent in unilateral co-regulation. This finding suggests that while the interactions became less synchronous during the latter half of the first year, they became more synchronous from 12-months onward. Although findings in the first year are contrary to those found by Evans and Porter (2009), our results may be capturing an important transition in the latter half of the first year, when infants are becoming more mobile and able to explore their environments independently. Furthermore, they reflect important developments in social-cognition and self-regulation that emerge in the second year of life. During this time, infants become more sophisticated in their ability to follow gaze (Flom & Johnson, 2011), imitate others (Meltzoff & Marshall, 2018), experience self-awareness (Rochat, 2003), and engage in shared intentionality (Tomasello et al., 2005). These developments likely also account for the decrease in time spent in asymmetrical co-regulation from 6- to 18-months in VLBW/preterm and, to a lesser extent, full-term dyads. Although dyads showed a marginal increase in asymmetrical co-regulation from 18-months onward, this may represent infants' developments in effortful control to regulate their attention towards the interactions (Johansson

et al., 2015), even if they were not contributing to it. The trajectory of psycho-socially at-risk dyads was more varied with an initial sharp decrease in asymmetrical co-regulation from 6- to 12-months followed by an increase to 18-months and another decrease to 48-months. It is unclear why asymmetrical co-regulation increased during the first half of the second year; future research should explore this finding further. It may result from lower levels of maternal sensitivity, which was previously found in the psycho-socially at-risk group (Stack et al. 2012). Following a history of less sensitive and more hostile (although still mild levels) maternal responses, infants may be less likely to contribute to the interaction. This may play a particularly large role at 18-months, whereby psycho-socially at-risk dyads engaged in more asymmetrical co-regulation than the other groups, and more disrupted interactions than the low-risk, full-term dyads.

The third objective was to examine associations between co-regulation and parenting stress. Our findings generally supported the hypotheses that parenting stress would be associated with less sensitive and reciprocal forms of co-regulation among the at-risk groups. Specifically, mothers who reported greater parenting stress engaged in more unilateral and less symmetrical co-regulation with their VLBW/preterm infants. Consistent with prior research into preterm infant-parent relationships (Sansavini et al., 2015; Neri et al., 2017) highly stressed VLBW/preterm dyads struggled to synchronize their interactions, with one member often disengaging from the interaction, despite the other's consistent engagement and occasional bids for attention. Surprisingly, maternal education was associated with greater time spent in asymmetrical co-regulation, which contrasts with past findings that maternal education is associated with increased maternal sensitivity (Neuhauser, 2018). Although asymmetrical co-regulation does not represent mutual reciprocity, it does require each member to regulate and

direct their attention towards each other and their interaction (i.e., mutual engagement). Interestingly, sex differences were also observed within the VLBW/preterm group, where girls engaged in more symmetrical co-regulation, while boys engaged in more unilateral co-regulation. However, it is possible that these differences may be due to temperament rather than sex. Else-Quest (2012) noted that boys tend to exhibit higher activity levels than girls, which may lead to decreased synchrony and mutual reciprocity, especially at a young age. Future research should examine this possible sex difference in co-regulation by examining potential third variables, such as temperament and reactivity.

The psycho-socially at-risk dyads' patterns of interactions were also associated with parenting stress, although somewhat differently than the VLBW/preterm group. Psycho-socially at-risk mothers who reported greater parenting stress engaged in less asymmetrical co-regulation with their infants. While this finding is contrary to our hypotheses, psycho-socially at-risk dyads with higher levels of parenting stress may be engaging in more problematic interactions that lacked co-regulation and were not captured by our analyses. For example, these dyads may have spent relatively more time in unengaged or disrupted interactions. However, these patterns occurred infrequently within our sample, and we likely did not have the power to detect such associations. Thus, it is unclear whether parenting stress was associated with these more problematic interactions. However, previous research has highlighted the compounding role of stress on mother-infant interactions (Doiron & Stack, 2017; Oyetunji & Chandra, 2020). Consistent with prior studies (Neuhauser, 2018), our findings did provide support for the protective role of maternal education in mother-infant interactions. Specifically, psycho-socially at-risk mothers with more years of education took part in fewer unengaged interactions. In other

words, interactions with these mothers were characterized by at least one member of the dyad being engaged in the interaction.

Limitations and Future Directions

Our findings provide important insight into the early development of mother-infant co-regulation in mother-infant dyads over the first years of life by highlighting the role of various forms of risk. While our results address important gaps in the literature on mother-infant interactions, we must also acknowledge some limitations of our study. Although certainly at a psycho-social and medical disadvantage, our at-risk groups were defined conservatively. That is, the VLBW/preterm group was strictly screened for medical issues outside of their VLBW/preterm birth status. This criterion ensured that differences in co-regulation from other groups were in fact due to their VLBW/preterm birth status and not other medical or psycho-social issues. However, in doing so, it limits the generalizability of our findings as VLBW/preterm births are often accompanied by a wide range of medical conditions and complications (Gonçalves et al., 2020). Furthermore, this criterion may have limited the differences between VLBW/preterm dyads and low-risk full-term dyads, as the VLBW/preterm group was a healthy sample. Given that previous research has found associations between additional medical conditions, stress, VLBW/preterm status, and mother-infant interactions and relationships (Muller-Nix et al., 2004, Neri et al., 2017; Oyetunji & Chandra, 2020), future research would benefit from including a broader range of VLBW/preterm dyads. However, notably the use of a conservative sample disentangles the early birth and the very low birthweight from other medical issues, that are often confounded in studies, and as such, serves as an important strength.

The psycho-socially at-risk group was similarly described conservatively. As mentioned, mothers were recruited in childhood from schools serving disadvantaged neighbourhoods. While some of these mothers certainly faced adversity in their development, some of the risk within their families may have diluted over time. That being said, the intergenerational transfer of risk is now widely accepted (Schoon & Melis, 2019), and co-regulative differences between psycho-socially at-risk and low-risk dyads found in the present study add to this growing literature.

Sample size also posed an issue for the present study, as attrition may have limited our power to find differences in co-regulation and its association with stress. These limitations to power necessitated aggregating parenting stress over time to limit the number of predictors entered into the model. Furthermore, the parent-child dysfunction and difficult child subscales of the PSI-3, showed limited stability over time, which may have impacted our ability to detect results. However, the intensive and longitudinal nature of the study, which included home visits and questionnaires, was extremely informative for the development of co-regulation in a naturalistic setting. At the same time, it may have also been challenging for dyads to participate consistently at each time point. While logistically difficult and resource intensive, longitudinal research is crucial to the understanding of developmental phenomena. Given the limited number of longitudinal studies on co-regulation, adopting a longitudinal design in future research is highly recommended.

Observing mother-infant dyads interact in a free play setting within their homes provided a naturalistic setting and increased generalizability of the study. However, research from Aureli et al. (2018) indicates that co-regulation is heavily influenced by context. Using only the free play task may have limited the variability of patterns of co-regulation that the dyads engaged in. It may have also put pressure on mothers to engage in the interaction more than they would have

otherwise, since they were given directions to “play with their children as they normally would”. Future research would benefit from examining co-regulation in a range of settings, including, but not limited to free play. For example, co-regulation could be observed in additional naturalistic settings that involve more people (e.g., family dinners), interactions among other infants or children (e.g., peers or siblings), and in mildly stressful situations (e.g., an interruption task where one member is occupied with a task). Given that co-regulation is an ongoing, dynamic process, shaped by dyadic histories (Fogel, 1993), observing co-regulation in a range of settings with different people and relationships is crucial to understanding its development.

Our study captured elements of risk, including medical and psycho-social, that are associated with co-regulation. Additional factors may also impact these associations. Child factors, such as temperament have been shown to influence parenting approaches and interactions (Dalimonte-Merckling & Brophy-Herb, 2019) and may in part account for the sex differences found in our study. Additional factors, including history of interactions with others such as siblings, peers, and other caregivers, may also dynamically shape the way infants and mothers co-regulate. Thus, further investigation of the development of synchrony and asynchrony in these relationships is warranted and a deeper consideration of varying levels of exposure to others in the infancy years is recommended. Furthermore, while the Dynamic Systems approach to understanding interactions and relationships advises against breaking down interactions into individual behaviors (Fogel, 1993), future research may benefit from distinguishing between active and passive partners during asynchronous forms of co-regulation (i.e., asymmetrical and unilateral patterns). Doing so would allow for a deeper understanding of how each individual’s unique risk factors and ways of interacting contribute to mother-infant co-regulation.

In sum, future research is encouraged to examine co-regulation in a broader range of contexts and risk groups considering the role of parent stress. Given previous research findings that patterns in parent-child interactions predict later interactions with others (Feldman et al., 2013) and later psycho-social adjustment (Gilbert & Gilbert, 2013), future longitudinal studies are warranted to explore the outcomes of co-regulation, including consequences for social interactions with other family members and peers, and for psychopathology, and the intergenerational transfer of risk.

Conclusions

Taken together, our findings highlight the importance of accounting for contextual risk factors when examining co-regulation in mother-infant dyads. Even within conservative risk groups (i.e., exclusion criteria included screening for serious medical issues), differences in co-regulation were found. Midway through the second year of life, psycho-socially at-risk infant-mother dyads took part in more interactions characterized by mutual engagement but lacking in reciprocity. This supports the notion that psycho-social risk may lead infants to withhold their contributions to the interaction, perhaps due to previous experiences whereby mothers struggled to attend and respond to infants' social cues. Furthermore, parenting stress appears to play a compounding role in co-regulation for at-risk groups specifically. Among both the medically and psycho-socially at-risk infant-mother dyads, mothers reporting higher stress engaged in less synchronous and more asynchronous forms of co-regulation. These findings indicate that mothers struggle to respond sensitively to their infants when stressed and this may also impact infants' interactive behaviors. Importantly, maternal education served as a protective factor against these more asynchronous interactions. Finally, results from our study provide insight into the development of co-regulation over the first 48-months of life, showing that its development

is not linear, but rather complex and likely intertwined with social-cognitive developments and dynamic changes in the mother-infant relationship. Overall, however, all groups showed a general trend towards increasing synchrony from 12- to 18-months onward.

Our findings have implications for the importance of early interventions aimed at mother-infant relationships in at-risk contexts. Early interventions focused on alleviating parenting stress and providing education opportunities to mothers in adverse situations may lead to more time spent in sensitive and reciprocal interactions with their infants, and less asymmetrical interactions. Importantly, the former interactions have shown favorable outcomes for both the infant and the mother-infant relationship (Evans & Porter, 2009). Furthermore, previous research has shown favorable outcomes for parent-child relationships mothers have access to additional resources, including social supports and other mental health initiatives (Balaji et al., 2007; Rahman et al., 2013).

Our findings shed light on the complex and dynamic processes involved in mother-infant co-regulation in the early years of life. Our study also underscores the role of risky contexts in the dyad's ability to maintain synchrony and engage in mutual reciprocity, both of which are crucial processes in the development of healthy relationships.

Table 1

Descriptive Statistics and Stability of Co-Regulation and Parenting Stress Index (PSI)

		Full-term		VLBW/preterm		Psycho-socially at-risk		Correlations across age (stability)		
Co-regulation patterns	Age	*M*	*SD*	*M*	*SD*	*M*	*SD*	12	18	48
Symmetrical	6	0.62	0.14	0.47	0.19	0.6	0.18	0.09	0.16	0.15
	12	0.53	0.09	0.55	0.18	0.59	0.13	-	0.15	0.19
	18	0.73	0.17	0.75	0.14	0.7	0.16	-	-	0.13
	48	0.91	0.06	0.9	0.07	0.92	0.06	-	-	-
Asymmetrical	6	0.11	0.11	0.12	0.11	0.11	0.08	0.1	0.07	-0.02
	12	0.09	0.05	0.1	0.08	0.06	0.04	-	-0.03	0.12
	18	0.05	0.04	0.04	0.03	0.08	0.08	-	-	-0.01
	48	0.04	0.03	0.04	0.04	0.02	0.04	-	-	-
Unilateral	6	0.25	0.12	0.3	0.14	0.27	0.16	-0.005	-0.003	0.13
	12	0.36	0.11	0.34	0.17	0.33	0.13	-	0.23*	0.16
	18	0.2	0.15	0.2	0.13	0.19	0.12	-	-	0.17
	48	0.03	0.04	0.04	0.04	0.04	0.04	-	-	-
Unengaged	6	0.0003	0.002	0.002	0.005	0.002	0.004	-0.04	0.17	0.008
	12	0.02	0.02	0.008	0.01	0.008	0.01	-	0.32**	-0.002
	18	0.02	0.03	0.008	0.02	0.01	0.02	-	-	-0.03
	48	0.01	0.01	0.02	0.02	0.02	0.02	-	-	-
Disruption	6	0.01	0.04	0.01	0.03	0.02	0.03	-0.06	-0.1	-0.003
	12	0.003	0.007	0.007	0.02	0.009	0.03	-	-0.05	0.25*
	18	0.0007	0.002	0.004	0.01	0.01	0.03	-	-	0.23*
	48	0.001	0.003	0.003	0.01	0.002	0.005	-	-	-
PSI scales	Age	*M*	*SD*	*M*	*SD*	*M*	*SD*	12	18	48
Parent distress	6	21.91	6.67	25.31	7.85	22.91	7.44	0.64**	0.63**	0.51**
	12	21.57	6.31	26.07	9.26	23.31	8.14	-	0.58**	0.56**
	18	22.5	8.82	25.89	8.73	21.79	8.28	-	-	0.51**

	48	21.67	8.12	24.94	8.21	22.79	7.48	-	-	-
Parent-child dysfunction	6	14.89	4.01	18.25	6.79	15.19	3.14	0.53**	0.36**	0.30**
	12	15.35	3.56	17.45	5.2	15.45	3.14	-	0.39**	0.35**
	18	16.31	7.66	17.69	6.03	15.86	4.39	-	-	0.29**
	48	14.67	1.94	18.14	6.19	17.07	4.83	-	-	-
Difficult child	6	18.32	4.7	21.39	8	18.61	6.28	0.44**	0.47**	0.34**
	12	22.6	4.96	25.15	6.41	23.5	5.67	-	0.54**	0.42**
	18	23.58	6.66	23.69	6.46	21.43	7.37	-	-	0.45**
	48	25.44	5.71	27.23	9.17	25.79	5.28	-	-	-
Total stress	6	55.13	12.17	64.95	18.68	56.7	12.94	0.61**	0.65**	0.49**
	12	59.52	12.07	68.67	15.77	62.26	13.85	-	0.70**	0.56**
	18	62.39	17.92	67.28	14.93	59.09	17.28	-	-	0.50**
	48	61.78	12.94	70.31	21.19	65.64	14.42	-	-	-

Note. $N = 48$ full-term, 61 VLBW/preterm, 54 psycho-socially at-risk. Ages are in months.
*$p < .05$, **$p < .01$, two-tailed.

Table 2

Final Models for Parenting Stress, Maternal Education, and Infant Sex Predicting Proportion of Time Spent in Co-Regulation From 6- to 48-Months

			Symmetrical	Asymmetrical	Unilateral	Unengaged
Fixed Effects						
Full-term						
Initial status	Intercept	γ_{00}	109.28 (8.19)***	4.21 (4.23)	-18.43 (8.79)*	0.67 (1.51)
	Total parenting stress mean	γ_{01}	--	--	--	--
	Total parenting stress variation	γ_{02}	--	--	--	--
	Parent distress mean	γ_{03}	--	--	0.16 (0.23)	--
	Parent distress variation	γ_{04}	--	--	-0.25 (0.17)	--
	Maternal education	γ_{05}	--	--	--	--
	Sex	γ_{06}	--	--	--	--
Linear rate of change	Intercept	γ_{10}	50.42 (8.29)***	-1.94 (4.90)	-48.25 (7.87)***	-0.85 (1.88)
Quadratic rate of change	Intercept	γ_{12}	-10.92 (2.68)***	1.06 (1.26)	9.76 (2.36)***	0.09 (0.48)
Cubic rate of change	Intercept	γ_{13}	-13.91 (2.74)***	-0.02 (1.67)	13.92 (2.62)***	0.34 (0.67)
VLBW/preterm						
Initial status	Intercept	γ_{20}	100.76 (12.10)***	-15.21 (7.27)*	-4.41 (9.30)	0.68 (0.90)
	Total parenting stress mean	γ_{21}	-0.17 (0.11)t	--	--	--
	Total parenting stress variation	γ_{22}	--	--	--	--
	Parent distress mean	γ_{23}	--	--	0.42 (0.71)*	--
	Parent distress variation	γ_{24}	--	--	0.06 (0.17)	--
	Maternal education	γ_{25}	--	1.19 (0.49)*	--	--
	Sex	γ_{26}	6.84 (3.32)*	--	-4.77 (2.26)*	--
Rate of change	Intercept	γ_{30}	38.10 (10.64)***	-7.57 (4.76)	-30.60 (9.00)**	0.01 (0.97)
Quadratic rate of change	Intercept	γ_{31}	-9.00 (2.90)**	2.88 (1.31)*	6.10 (2.43)*	0.02 (0.29)
Cubic rate of change	Intercept	γ_{32}	-9.72 (3.55)**	1.88 (1.58)	7.80 (3.00)**	0.06 (0.32)
Psycho-social risk						
Initial status	Intercept	γ_{40}	88.63 (9.38)***	20.08 (5.44)***	-12.91 (9.62)	3.54 (1.23)**

	Total parenting stress mean	γ_{41}	--	-0.08 (0.05)t	--	-0.01 (0.06)
	Total parenting stress variation	γ_{42}	--	--	--	--
	Parent distress mean	γ_{43}	--	--	0.27 (0.24)	--
	Parent distress variation	γ_{44}	--	--	-0.13 (0.23)	--
	Maternal education	γ_{45}	--	--	--	-0.13 (0.06)*
	Sex	γ_{46}	--	--	--	--
Rate of change	Intercept	γ_{50}	26.07 (10.33)*	9.00 (0.05)t	-36.04 (9.10)***	0.05 (0.83)
Quadratic rate of change	Intercept	γ_{51}	-4.49 (2.88)	-2.73 (1.38)*	7.58 (2.49)**	-0.03 (0.25)
Cubic rate of change	Intercept	γ_{52}	-5.74 (3.46)	-3.67 (1.62)*	9.70 (3.03)**	0.06 (0.27)
Variance/residual variance components						
Full-term	In initial status	σ_0^2	144.55 (20.10)***	46.78 (10.49)***	117.89 (18.12)***	3.60 (1.15)**
VLBW/preterm	In initial status	σ_0^2	164.82 (19.41)***	47.78 (7.61)***	124.10 (15.25)***	2.15 (0.46)***
Psycho-social risk	In initial status	σ_0^2	160.92 (19.66)***	33.48 (5.98)***	129.08 (15.39)***	2.39 (0.43)***
Goodness-of-fit	LL		-5209.57	-4769.57	-4669.86	-3820.36
	AIC		10459.15	9579.14	9389.71	7680.72
	BIC		10548.75	9668.74	9501.71	7770.32

Note. Model goodness-of-fit indices include LL = Loglikelihood, AIC = Akaike, and BIC = Bayesian.
*$p < .05$, **$p < .01$, ***$p < .001$ (two-tailed).

Table 3

List of Abbreviations

Abbreviation	Definition
DIQ	Demographic Information Questionnaire
ELGA	Extremely low gestational age
FT	Full-term
ICC	Intraclass coefficients
MANOVA	Multivariate analysis of variance
MLM	Multilevel growth modelling
NICU	Neonatal intensive care unit
PSI-3	Parenting Stress Index, third edition
RRCS	Revised Relational Coding System
VLBW/preterm	Very low birthweight/preterm

Figure 1

Time Spent in Symmetrical Co-Regulation from 6- to 48-months of Age in Full-Term, VLBW/Preterm, and Psycho-Socially At-Risk Infant-Mother Dyads

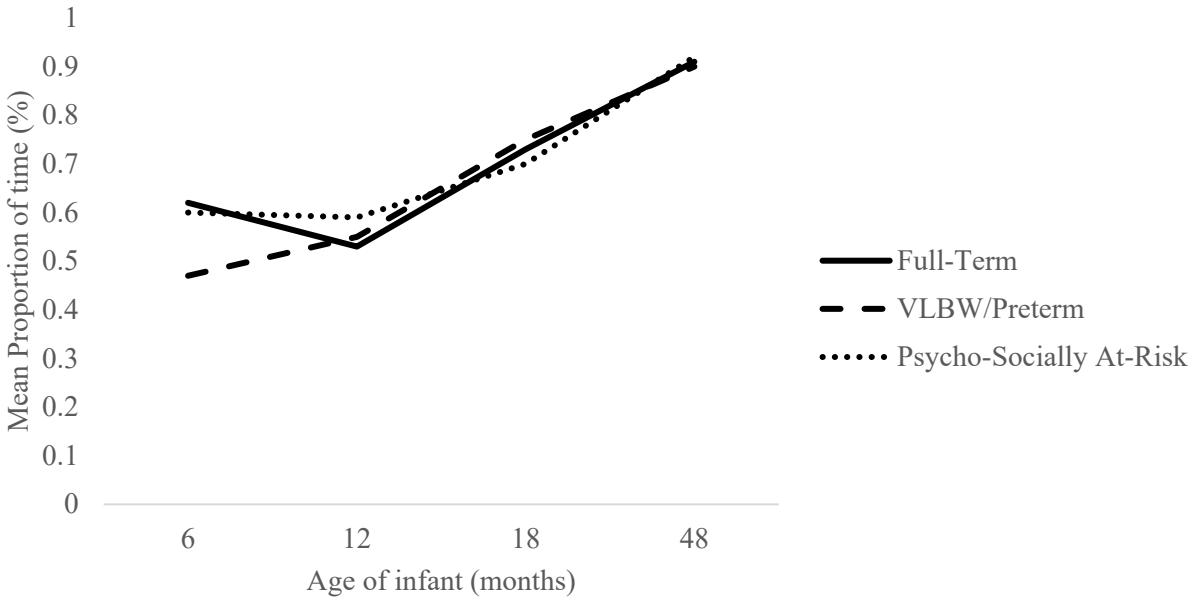


Figure 2

Time Spent in Asymmetrical Co-Regulation from 6- to 48-months of Age in Full-Term, VLBW/Preterm, and Psycho-Socially At-Risk Infant-Mother Dyads

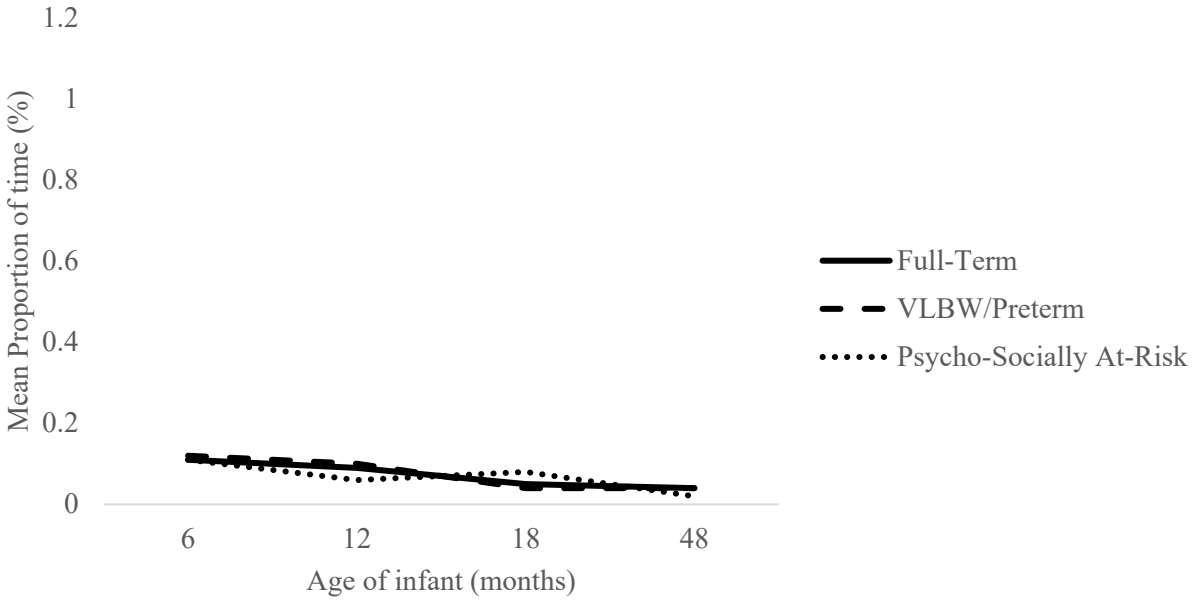
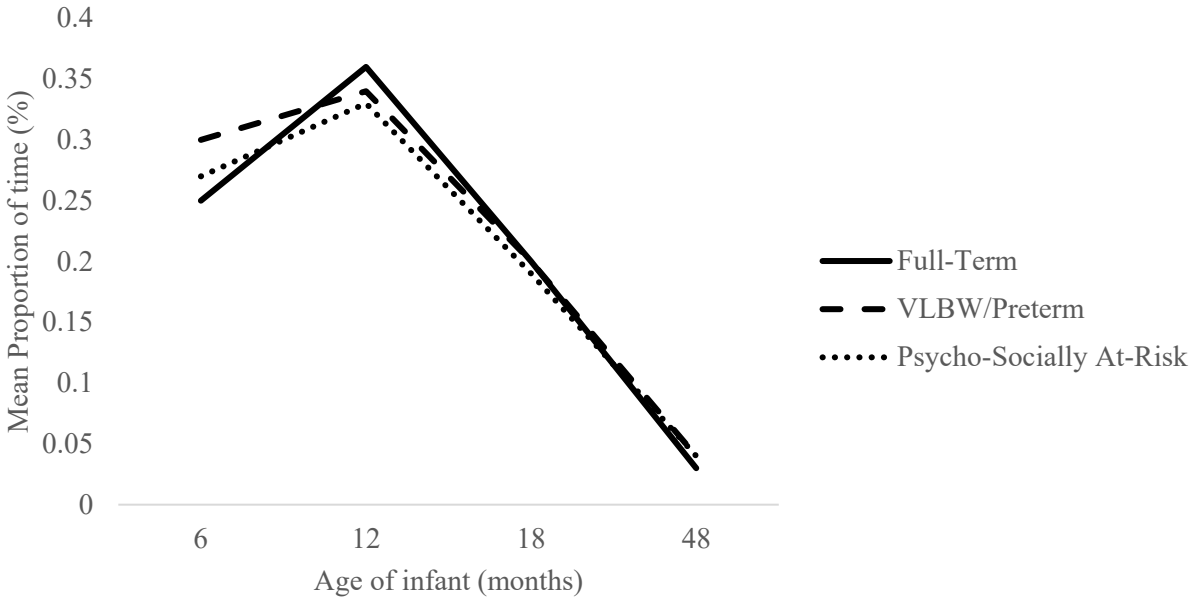


Figure 3

Time Spent in Unilateral Co-Regulation from 6- to 48-months of Age in Full-Term, VLBW/Preterm, and Psycho-Socially At-Risk Infant-Mother Dyads



Chapter 3: Transition Statement Between Studies 1 and 2

Results from Study 1 broadened our understanding of the development of co-regulation from infancy into early childhood among low- and at-risk infant-mother dyads. Using an observational approach, we found that psycho-socially at-risk dyads took part in more interactions whereby one member carried the interaction, while the other passively watched than their full-term and VLBW/preterm counterparts at 18-months of age. They also displayed more difficulty co-regulating than full-term dyads, as evidenced by more time spent emotionally dysregulated following miscommunication between mother and infant. That said, the developmental patterns of co-regulation over the first 4 years of life were complex and expanded on the current literature, which to date has focused almost entirely on co-regulation in infancy (Aureli & Presaghi, 2010; Aureli et al., 2018; Doiron & Stack, 2017; Evans & Porter, 2009; Hsu & Fogel, 2003), despite it being a lifelong dynamic process (Fogel, 1993). Overall, our results indicated that across all groups, dyads engaged in more one-sided forms of co-regulation over the first year, then became progressively more synchronous during late infancy and early childhood. Study 1 further added to the literature on co-regulation by highlighting how parenting stress and demographic factors complicate the development of co-regulation, particularly in at-risk groups. Specifically, mothers who reported higher levels of parenting stress engaged in less reciprocal and less synchronous interactions with their infants over time. In addition, maternal education seemed to buffer against these one-sided interactions, and girls engaged in more synchronous forms of co-regulation with their mothers than boys (see Appendix H for more details about how analyses were conducted).

While Study 1 expanded our knowledge on co-regulation by providing a description of its development into early childhood among low- and at-risk dyads, it did not delve into what these

patterns of co-regulation mean for children's outcomes. In other words, it remained unclear how co-regulation impacted children's mental health. Study 2 was designed to address this question while accounting for the complex associations between risk status, parenting stress, and co-regulation highlighted by Study 1. Given the dearth of findings currently available for early to middle childhood, Study 2 focused on child-mother co-regulation at 4.5 years of age in low- and at-risk dyads. This age group was also chosen for the significant developments and transitions that children are undergoing during this stage of development, including entry into preschool and school and major gains in social cognitive development (Santos et al., 2014). Since findings from Study 1 indicated associations between parenting stress and co-regulation, Study 2 used separate moderation analyses for each group of child-mother dyads to explore how the interactions between parenting stress and different patterns of co-regulation were associated with concurrent children's mental health at 4.5 years of age. Study 2 also sought to examine the longitudinal associations between co-regulation, parenting stress, and children's mental health. It was hypothesized in Study 2 that asynchronous forms of co-regulation would interact with higher levels of parenting stress to predict more internalizing and externalizing problems in children, both concurrently and longitudinally, particularly among the at-risk dyads.

Chapter 4: Dissertation Study 2

Moderating Effects of Mother-Child Co-Regulation on the Association Between Parent Stress and Child Mental Health in Pre-Schoolers in Low- and At-Risk Dyads

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Acknowledgements: This research was financially supported in part by grants from the Social Sciences and Humanities Research Council of Canada (SSHRC), Fonds de recherche du Québec – Société et culture (FRQ – SC), Centre for Research in Human Development (CRDH), and Concordia University awarded to Dale M. Stack (PI) and co-investigators, graduate student fellowships awarded to Kelly Doiron from SSHRC and Concordia, and Concordia University for the Concordia Horizon Post-Doctoral fellowship and Faculty of Arts and Science top up award awarded to Kalee De France. The authors gratefully acknowledge Sarah Al-Kawas for assistance with some of the coding, Victoria Lane and Laurie Houle for help with manuscript preparation, as well as the research teams involved in the data collection phases. We would also like to thank the Concordia Project team and other members of our research team over the years for their assistance at various points with data management and collection. The Concordia Longitudinal Research Project originated in 1976 under the direction of Jane Ledingham and Alex E. Schwartzman. The project is currently directed by Lisa A. Serbin and Dale M. Stack. Gratitude is extended to the teaching hospital staff. Finally, we are most indebted to the families who participated in this study. The authors attest that there is no conflict of interest in the conduct or reporting of the current research.

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Abstract

Dyadic co-regulation between mothers and children is a crucial process in children's social-emotional development, yet few studies have explored co-regulation beyond infancy. Our study examined mother-child co-regulation in childhood and its roles in the association between parenting stress and mental health outcomes in children from low- and at-risk contexts. The objectives were to examine (1) the moderating effect of co-regulation on associations between parenting stress and child mental health in low-risk preschool-aged dyads, (2) the same effect in medically and psycho-socially at-risk dyads, and (3) the moderating effect of co-regulation at 4.5-years of age on the association between parenting stress (at 4.5-years) and child mental health at 7-years of age in psycho-socially at-risk dyads. Participants included three groups of child-mother dyads (full-term, $n = 27$; very low birthweight/preterm [VLBW/preterm] born at or before 33-weeks, weighing under 1500g, $n = 36$; psycho-socially at-risk with parent histories of socioeconomic disadvantage, $n = 44$). Dyads completed a free play task in their homes when children were 4.5 years old and again when children were 7-years old (psycho-socially at-risk group). Co-regulation was observationally coded using the *Revised Relational Coding System* (*RRCS*; Fogel et al., 2003), and mothers completed questionnaires on parenting stress and child mental health. Significant moderating effects of co-regulation were found. Among full-term dyads, a positive association between parenting stress and child internalizing outcomes emerged for those who spent more time in asynchronous forms of co-regulation. Opposite effects emerged in both at-risk groups, whereby positive associations between parenting stress and child internalizing and externalizing problems emerged among those who engaged in less asynchronous forms of co-regulation, and this was maintained when predicting child externalizing problems at 7-years of age. Our results underscore the differing moderating effects

of co-regulation in low- and at-risk groups in early and middle childhood, whereby less engaged and reciprocal forms of co-regulation were risky for low-risk dyads, but protective for at-risk groups.

Keywords: co-regulation, preschool, childhood, risk, parenting stress, VLBW/preterm, psycho-social risk, longitudinal, moderation

Moderating Effects of Mother-Child Co-Regulation on the Association Between Parent Stress and Child Mental Health During Preschool in Low- and At-Risk Dyads

From birth, parent-child interactions form a foundation from which children develop their relationships. Whenever parents and children interact, they both contribute to the evolution and management of that interaction through body language, eye contact, and conversation (Fogel, 1993). Thus, both parent and child *co-regulate* their interactions, mutually influencing each other in that process. Their interactions impact and are further impacted by their environment, history, and expectations for the future (Fogel, 1993; Sameroff, 2009). While certain characteristics of parent-child interactions, such as maternal sensitivity and child responsiveness have been shown to buffer against risky child outcomes, other factors, such as hostility, may exacerbate problems within the dyad, leading to poor child outcomes (Biringen et al., 2014). However, it is unclear how co-regulation of members of the dyad, together, mitigate or exacerbate these risk factors and outcomes.

Co-Regulation in Early Childhood

According to Dynamic Systems Theory, no interaction occurs in isolation (Fogel, 1993). While interacting, both partners (e.g., mother and child) are constantly anticipating the others' responses and adjusting their behaviors accordingly in a *dynamic* manner. Their interactions are influenced by the history of their relationship and the social, cognitive, and emotional abilities of each partner, which shape their expectations for how each will respond (Fogel, 1993). The interactions also occur in the context of the dyad's environment, which include stresses, family constellation, and resources that will further impact how that interaction unfolds (Sameroff, 2009). Furthermore, instead of focusing on discrete interactive behaviors of each individual, Fogel (1993) suggests exploring the interactive patterns of the dyad. In their study on 6-month-

old infant-mother dyads, Hsu and Fogel (2003) identified three patterns in the way dyads co-regulated their interactions: (1) symmetrical (both mother and child are reciprocally engaged in, and contributing to, the interaction), (2) asymmetrical (both mother and child are engaged with each other, but only one actively contributes to the interaction), and (3) unilateral (either the mother or child passively or actively attends to their disengaged partner). Unengaged and disruptive patterns of communication described the lack, or breakdown, of co-regulation. The former occurred when neither member was engaged with each other, while the latter involved the misunderstanding or ignoring of social cues leading to emotion dysregulation (Hsu & Fogel, 2003). While these patterns were initially described in mother-infant co-regulation, these general patterns summarize all interactions, including those with more than two people, people of all ages, and interactions between friends, family, and strangers (Fogel, 1993). Regardless of the context or people involved, co-regulation is necessary for adequate communication (Fogel, 1993).

To date, much of the research on interactive co-regulation has focused on infancy. Findings suggest that mother-infant dyads become increasingly symmetrical and less unilateral over the infant's first two years of life (Aureli & Presaghi, 2010; Evans & Porter, 2009). However, to the authors' knowledge, no studies have examined co-regulation of the interaction in this way beyond infancy. That being said, elements of co-regulation, including synchrony, reciprocity, and attunement have been associated with more favorable child outcomes during the preschool years (Provenzi et al., 2018). Research during infancy has indicated that more symmetrical co-regulation is associated with more positive outcomes in the mother-infant relationship (more secure attachments) and infant cognitive and motor development, than unilateral co-regulation (Evans & Porter, 2009; Sansavini et al., 2015). Furthermore, maternal

risk factors, such as parenting stress have been associated with disruptive interactive patterns during infancy (Doiron & Stack, 2017). However, it remains unclear how parenting stress and co-regulation interact to predict child outcomes.

Parenting Stress and Parent-Child Interactions

Parenting stress has long been associated with negative outcomes in both parents and children (Anthony et al., 2005; Hentges et al., 2019; Mackler et al., 2015; McQuillan et al., 2019). For example, Crnic et al. (2005) found that parents' stressful life events and daily parenting hassles predicted greater negativity and behaviour problems in preschool children. Conversely, they found that less stress predicted more positive parenting and pleasure derived from interactions with their children. The latter finding is consistent with research showing that parenting stress is also associated with the parent-child dynamic (McQuillan et al., 2019). In a study focusing specifically on co-regulation as noted above, higher parenting stress was associated with more time spent in disruptive interactions between mothers and their infants (Doiron & Stack, 2017). Furthermore, consistent with Sameroff's (2009) Transactional Model, certain family, child, and parent characteristics impact parenting stress. Mikolajczak et al. (2018) found that parent characteristics, parenting, family dysfunction, and, to a lesser extent, child and demographic characteristics predicted parent burnout, a chronic form of parenting stress. Results from their study highlight the importance of examining dynamics within the family, including interactions between parents and children, to better understand the predictors and outcomes of parenting stress (Mikolajczak et al., 2018). While certainly important, the majority of the research to date has focused primarily on discrete measures of parenting, parent characteristics, and child characteristics, rather than dyadic patterns in their interactions.

The association between parenting stress and parenting practices has been well established, with higher levels of parenting stress associated with more authoritarian and permissive parenting styles (McQuillan & Bates, 2017). According to Fonseca et al. (2020), highly stressed mothers struggle to regulate their emotions and behaviors to respond sensitively to their children. This is consistent with findings from Crandall et al.'s (2015) literature review, indicating that parents' limited executive functioning abilities were associated with harsher, reactive parenting, which may serve to further increase parental distress, as parents use ineffective discipline and inadvertently increase problematic behaviors in their children (Dennis, 2006; McQuillan & Bates, 2017). Likewise, child characteristics, such as temperament (i.e., how they generally react and respond to situations), have also been shown to predict, and be an outcome of, parenting stress (McQuillan & Bates, 2017). In Pesonen et al.'s (2008) longitudinal study they found a bidirectional relationship between higher negative emotionality in children and increased maternal stress over the first 5 years of life. However, the effect of maternal stress on child outcomes was notably greater than the effect of child temperament on maternal stress (Pesonen et al., 2008).

While parenting is inevitably stressful at times, certain lived experiences exacerbate that stress. These include, daily hassles, feeling less effective, conflict between parents, chaos in the home, and sleep interruptions (McQuillan & Bates, 2017). Lived experiences also include adversity faced by parents in their own childhoods. Higher instances of these adverse childhood experiences have been associated with more parenting stress, which in turn led mothers to perceive their children as being more difficult to manage (Lange et al., 2019). Importantly, these adverse experiences are significantly higher among those living in poverty (Steele et al., 2016).

These findings highlight the importance of including disadvantaged groups in studies, who are disproportionately vulnerable to, and affected by, parenting stress.

Events during parenthood, such as the birth of an infant with medical complications, also contribute to parents' distress. In a study on parents of VLBW/preterm infants, Treyvaud (2014) found that these parents experienced considerable distress about meeting the high needs of their infants. Further studies showed that mothers were vulnerable to depression and distress when their infants were VLBW (Agostini et al., 2014; Neri et al., 2017). This stress in turn impacts the infant-parent relationship. For example, multiple studies have demonstrated that mothers with high levels of stress engaged in more controlling and less sensitive interactions with their preterm infants (Forcada-Guex et al., 2011 Muller-Nix et al., 2004; Neri et al., 2017). While results from some studies suggest that the negative impacts of VLBW/preterm birth on parent mental health and parenting practices diminish over time (Rowe & Jones, 2010; Treyvaud, 2014), other researchers noted long term effects going well into childhood (Voigt et al., 2013). In a longitudinal study examining parenting stress from birth to 3 years of age, mothers of high-risk, but not low-risk, VLBW infants reported significantly more parenting stress when children were 3-years old (Singer et al., 1999). In a study following a similar timeline, parenting stress moderated the association between infant distress in the neonatal period and child negative reactivity in the preschool period (Voigt et al., 2013). Furthermore, the trajectories of parenting stress in mothers of VLBW/preterm children over time differ depending on various factors including multiple versus single births, gestational age, days hospitalized, additional health risks, SES, social support, and parent mental health (Spinelli & Bolt, 2013). The studies point to the importance of considering parenting stress in parent-child interactions, particularly in the context of medically at-risk infants. While research to date has highlighted co-regulative differences

between preterm and full-term infants (Doiron & Stack, 2017; Sansavini et al., 2015), less attention has been given to the role that parenting stress may play in these differences.

Parent-Child Interactions and Child Mental Health

As mentioned, many factors, both within and outside of parent-child dyads work bi-directionally to influence outcomes in children (Liu et al., 2019; Sameroff, 2009). Child temperament, specifically negative affect and effortful control have been studied extensively, with more negative affect and less effortful control generally leading to more negative mental health outcomes (McQuillan & Bates, 2017). Parenting behaviors have also been a common area of exploration, and there is a growing consensus that warm, sensitive, and responsive caregiving fosters favorable mental health outcomes in children (Bernier et al., 2021; Kok et al., 2013; van der Voort et al., 2014). Conversely, hostile, controlling, or permissive styles of parenting have been associated with more negative mental health outcomes, including both internalizing and externalizing problems in children (Carapito et al., 2020; Hosokawa & Katsura, 2019). Following much research focusing on either child *or* parent factors in child mental health outcomes, more studies are looking at the interaction of these factors. A longitudinal study following caregivers and their children from 2.5 to 5 years of age, found that hostile parenting interacted with infant anger to predict later child problems (Edwards & Hans, 2015). These child problems at 5-years were associated with additional risk factors, including having younger mothers with anxious and depressive symptoms, and family conflict (Edwards & Hans, 2015). Results from this study highlight the bi-directional nature of mother-child interactions and the implications of those interactions for later child outcomes. Furthermore, a study examining preschool-aged children and their caregivers found that children's negative affect (and less effortful control), poor family functioning, and maternal negative affect were associated with

higher levels of child internalizing symptoms (Crawford et al., 2011). The importance of the parent-child relationship was also highlighted in the development of disruptive behaviors, with findings from another study indicating that difficult parent-child relationships were associated with more externalizing problems and less prosocial behavior in preschool-aged children (Ruiz Ortez & Barnes, 2019). While child temperament has also been implicated in the development of externalizing problems, Padilla et al. (2020) found this association only for those whose mothers had fewer years of education. This again points to the complex influences of child characteristics, parent factors, and broader environmental risk factors.

The early influences of child mental health are important to study, as the outcomes extend far beyond childhood, and well into adolescence (Davis et al., 2015). In a 9-year longitudinal study that followed children from 3 to 12 years old, Finsaas et al. (2020) found that internalizing and externalizing problems in childhood predicted poor functioning in adolescence. Thus, investigating the role of parent stress, parent-child interactions, and child outcomes has important implications, both concurrently and beyond childhood.

The Present Study

The present study sought to address gaps in the co-regulation literature by focusing on mother-child interactions in early childhood and examining how these interactions interact with parent stress and child mental health. Both the preschool and school-age periods are times of significant social developments where children make notable gains in their language skills (Durkin, 2012), sustained attention (Jones et al., 2003), and social-cognitive abilities (Santos et al., 2014). They also take part in important transitions into daycare and school that further challenge and develop their socio-emotional skills. In line with Sameroff's (2009) Transactional Model, in the present study we considered various mutual influences between child, mother, and

the broader environment. Mother-child interactions were observationally coded for co-regulation using the *Revised Relational Coding System* (RRCS, Fogel et al., 2003), which emphasizes dyadic patterns over discrete behaviors. Furthermore, participants with various low- and at-risk backgrounds were recruited to broaden our understanding of co-regulation.

The objectives were to examine (1) the moderating effect of co-regulation on the concurrent association during preschool between parenting stress and child mental health in low-risk child-mother dyads, (2) the same effect in at-risk, namely psycho-socially at-risk and medically at-risk, child-mother dyads, and (3) the moderating effect of co-regulation on the longitudinal association between parenting stress during preschool and child mental health in middle childhood among psycho-socially at-risk child-mother dyads.

It was hypothesized that more reciprocal and engaged forms of co-regulation (i.e., symmetrical co-regulation) would have a protective moderating effect on the association between parenting stress and child mental health in all groups, albeit stronger in the risk groups. Conversely, less reciprocal and less engaged interactions (i.e., asymmetrical, unilateral, unengaged, and disruptive co-regulation) would have a risky moderating effect on the association between parenting stress and child mental health in all groups, with the effect again being strongest in the at-risk groups. It was also hypothesized that the interaction between parenting stress and co-regulation at 4.5-years (T1) would extend to later child mental health outcomes (internalizing, externalizing, and total problems) at 7-years (T2) in the psycho-socially at-risk group.

Methods

Participants

The sample for the present study was drawn from a larger, longitudinal study, which followed infant-mother dyads from 6-months to 4.5-years of age. This subsample focused on the 4.5-year timepoint and included 105 dyads from 3 groups of varying risk: children born full-term, children born VLBW/preterm, and children with family histories of psycho-social risk (see Table 1 for medical and demographic information). The initial 2 groups were recruited from a large teaching hospital in Montreal, Canada and matched for infant age, sex, and maternal education, while the psycho-socially at-risk group were drawn from a large prospective, intergenerational longitudinal study (Concordia Longitudinal Research Project). All dyads communicated in either French or English.

Full-Term

Twenty-seven full-term children and their mothers participated in the study at 4.5-years-old (M = 55 months, SD = 4.84 months; 13 males and 14 females). All children were born between 37- and 41-weeks gestation (M = 39.44, SD = 0.97) and weighed greater than 2,500 grams at birth (M = 3510.63, SD = 361.40). Recruitment occurred through birth records from a teaching hospital, where mothers were provided letters outlining the study and contacted by telephone to volunteer in the study. The mean age of mothers at the time of observation was 34.04 years (SD = 5.35).

VLBW/Preterm

Thirty-six VLBW/preterm children and their mothers participated in the study at 4.5-years-old (M = 59.02 months, SD = 8.26 months; 19 males and 17 females). To qualify as VLBW/preterm, children were born before 34-weeks gestation (M = 28.63, SD = 2.54) and with a birthweight under 1,500 grams (M = 1100.47, SD = 252.03). They were also screened for serious medical issues (e.g., congenital health problems) and lived with their biological mothers

who were at a low risk of psycho-social problems. Thus, the children were relatively healthy, aside from their VLBW status and premature birth. Dyads were recruited from the same teaching hospital as the full-term dyads, in collaboration with the chief neonatologist and the VLBW follow-up clinic. As such, they were also given a letter outlining the study and contacted by a follow-up clinic nurse over the telephone to volunteer in the study. The mean age of mothers at the time of observation was 38.29 years (*SD* = 5.19).

Psycho-Socially At-Risk

Forty-two children and their mothers, who had family histories of psycho-social risk participated in the study at 4.5-years-old (T1: *M* = 55.74 months, *SD* = 5.74 months; 17 males and 25 females) and 7-years-old (T2: *M* = 7.55 years, *SD* = 0.65 years, 15 males and 20 females). The children were born between 37- and 43-weeks gestation (*M* = 39.88, *SD* = 1.47) and weighed between 2730 to 4773 grams at birth (*M* = 3490.90, *SD* = 487.73). As mentioned, this group was composed of a subsample of a larger, prospective, longitudinal, intergenerational study (Concordia Project), in which the current mothers were recruited in childhood, in grades 1, 4, and 7 from schools serving disadvantaged neighborhoods in Montreal, Canada. The initial recruitment took place in 1976-1978 and families continue to be followed to the present day. A more detailed description of the Concordia Project sample can be found in Schwartzman et al. (1985), Serbin et al. (1998), and Stack et al. (2017). The mean age of mothers at the time of the 4-year-old timepoint observation was 33.26 years (*SD* = 3.38).

Procedure

At 4.5 years old, children and their mothers were visited by researchers at their homes. The study and procedure were explained, and written informed consent was obtained from the mothers. Dyads then engaged in a video-taped, 15-minute, free play session in a quiet, well-lit

room on a floormat, with mothers asked to "play as they normally would" and reminded that they could stop the procedure at any time. During the free play task, they were provided with age-appropriate, standardized toys, including a doll, comb, brush, tea set, telephone, Lego, and two books. Mothers were also interviewed and asked to complete a package of questionnaires during the 4.5-year-old visit. Mothers from the psycho-socially at-risk group were mailed an additional package of questionnaires to complete when their children were 7 years old.

Measures

Questionnaire Measures

Demographic Information Questionnaire. The Demographic Information Questionnaire (DIQ) was completed by mothers when their children were 4.5- and 7-years old (T2 for the psycho-socially at-risk group only). The DIQ reliably collects socio-demographic information, including maternal level of education, family characteristics, and child health. It has been used in various past studies from our laboratory (e.g., Briscoe et al., 2017; De Genna et al., 2007; Mantis et al., 2014).

Parenting Stress Index. Mothers completed the short form version of the Parenting Stress Index, third edition (PSI-3; Abidin, 1995) when their children were 4.5- and 7-years old (the latter T2 for the psycho-socially at-risk group only). This self-report measure collects information on stress brought on by parenting and the parent-child relationship. It is divided into three subscales that load onto the total stress score (overall parenting stress). The subscales consist of parenting distress (stress induced by one's role as a parent), parent-child dysfunction (perceived difficult interactions between parents and children), and difficult child (perceived trouble of parents managing their children). Mothers answered 36 items on a 5-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5). To facilitate interpretation of the

results, PSI-3 scores were reverse-coded with higher scores indicating more parenting stress. Previous research on normative samples has indicated high validity and reliability (Abidin, 1995; Haskett et al., 2006). Internal consistencies of all subscales ranged from .80 to .91 for the present study.

Child Behavior Checklist. The Child Behavior Checklist (CBCL) is a parent-report portion of the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach, 1991) that was completed by mothers when their children were 4.5- and 7-years old (the latter T2 for the psycho-socially at-risk group only). The questionnaire explores behavioral and emotional problems in children through 3-point Likert scale questions ranging from *absent* (0) to *occurs often* (2). Scores on the internalizing problems, externalizing problems, and total problems scales were analyzed for the present study.

Observational Measures

Co-Regulation. The *Revised Relational Coding System* (RRCS; Fogel et al., 2003) was used to observationally code patterns of co-regulation between mothers and children at 4.5-years of age in video recordings of the free play task. The RRCS codes the *interaction* of the dyad, rather than discrete behaviors. The codes are assigned according to how the dyad communicates, responds, and relates to each other through body language, eye contact, and vocalizations. These codes vary depending on the level of engagement in the dyad's interaction and how much they contribute to that interaction. They include three overarching patterns: symmetrical (both mother and child are engaged and contributing to the interaction), asymmetrical (both mother and child are engaged, while one member contributes to the interaction and the other is passive), unilateral (only one member of the dyad is engaged, while the other is unengaged). Two additional codes include disruption, which implies a breakdown of co-regulation due to misinterpretation or

disregard of social cues and emotional dysregulation, and unengaged, which occurs when both partners are disengaged from each other.

Although the RRCS also defines sub-codes, only the overarching codes were analyzed for the present study due to low variability in the sub-codes. An additional No Code was used for situations when the pattern of co-regulation could not be determined because a member of the dyad was outside of the frame, or their face was blocked.

Moment-to-moment coding of co-regulation was completed using the computer software program, Mangold INTERACT 7 (2020). The beginning and end of each pattern of co-regulation, lasting two seconds or more (as recommended by Fogel et al., 2003), was marked throughout each interaction. A second coder (senior undergraduate student, blind to the hypotheses of the study) trained on the RRCS coded one third of each sample to ensure reliability with the primary coder (graduate student who established reliability with another coder trained by the coding system developer's lab). Each pattern of co-regulation was analyzed for reliability, with kappa coefficients ranging from .80 to .90.

Analysis

Data Preparation

Data cleaning was completed using IBM SPSS Statistics (Version 27). After removing the "No Code" category, time spent in each pattern of co-regulation were converted to percent durations as a function of total time. Data were screened, and assumptions were checked for multiple regression and moderation analyses. Descriptive statistics were run on percent-durations for each pattern of co-regulation in each group to assess for normality through kurtosis and skew. Data were checked for outliers (i.e., data falling more than 3 *SD* from the mean) and converted to

the next most extreme score within 3 *SD*, as recommended by Kline (2009). Following this method of converting outliers, data was normally distributed.

Analytic Approach

To test the hypothesis that co-regulation moderates the association between parenting stress and child mental health, multiple regressions were conducted using the PROCESS add-on (Hayes, 2013) in SPSS. In each model, parenting stress (parent distress, parent-child dysfunction, or difficult child), co-regulation (symmetrical, asymmetrical, unilateral, unengaged, or disruption), and their interaction were entered as independent variables and child mental health (internalizing, externalizing, or total problems) as the dependent variable. Separate analyses were conducted for each group of participants (see Appendix H for more details about how analyses were conducted). Since power was limited due to sample size, no additional variables or controls were included. Only significant results are discussed. Conditional effects were assessed to explore the effect at different levels of the moderator (i.e., at the mean level of co-regulation and 1 *SD* above and below that mean). The Johnson-Neyman significance region was explored to determine more specifically at what level of co-regulation the moderating effect took place (Hayes, 2013).

Missing Data

One dyad in the VLBW/preterm group was excluded from the study due to incomplete questionnaires. Amongst the psycho-socially at-risk group, there was a 20% attrition rate in data collected from 4.5- to 7-years. Dyads missing at 7-years did not differ significantly from the non-missing dyads on any key demographic variables (i.e., child age, maternal age, birthweight, weeks gestations, and maternal education).

Results

Descriptive Statistics

A series of one-way ANOVAs were conducted to compare the low- and at-risk groups on each variable of interest (patterns of co-regulation and sub-scales of the PSI and CBCL). For co-regulation, groups only differed on the asymmetrical pattern, $F(2, 104) = 3.11$, $p < .05$. Sidak-corrected simple effects indicated that VLBW/preterm dyads spent more time in asymmetrical co-regulation ($M = 0.04$, $SD = 0.04$) than their psycho-socially at-risk counterparts ($M = 0.02$, $SD = 0.04$). For parenting stress, groups differed on the parent-child dysfunction sub-scale, $F(2, 102) = 4.07$, $p < .05$. Specifically, mothers of VLBW/preterm children reported more parent-child dysfunction ($M = 18.14$, $SD = 6.19$) than those of full-term children ($M = 14.67$, $SD = 1.94$). The groups did not differ on child internalizing, externalizing, or total problems reported by mothers on the CBCL in the preschool period. See Table 2 for full descriptive statistics. Prior to moderation analyses, intercorrelations were also examined (see Table 3).

Objective 1: Moderating Effect of Co-Regulation in the Concurrent Association Between Parenting Stress and Child Mental Health in Low-Risk Dyads

In low-risk, full-term preschool-aged dyads, the overall regression model of parent distress, time spent in asymmetrical co-regulation, and their interaction was significant, $F(3, 23) = 4.33$, $p < .05$, and accounted for 36% of the variance in child internalizing problems. Parent distress was nonsignificant, $b = .19$, $t(23) = .85$, $p = .40$, 95% CI [-0.27, 0.66], while asymmetrical co-regulation was significant, $b = -296.11$, $t(23) = -2.33$, $p < .05$, 95% CI [-559.06, -33.16]. The interaction between parent distress and asymmetrical co-regulation was also significant, $b = 14.92$, $t(23) = 2.12$, $p < .05$, 95% CI [0.38, 29.44] and indicated a positive association between parent distress and child internalizing problems among full-term dyads that

spent *average, b* = .73, *t*(23) = 2.82, *p* < .01, 95% CI [0.19, 1.27] and *high, b* = 1.22, *t*(23) = 2.76, *p* < .05, 95% CI [0.31, 2.14] amounts of time in asymmetrical co-regulation (see Figure 1). Specifically, parent distress was positively associated with child internalizing symptoms in full-term dyads who engaged in asymmetrical co-regulation at least 1.55% of the time, *t*(23) = 2.07, *p* = .05, *b* = .42, 95% CI [0.00, 0.85], and this association became increasingly stronger as dyads spent more time in asymmetrical co-regulation.

Objective 2: Moderating Effect of Co-Regulation in the Concurrent Association Between Parenting Stress and Child Mental Health in At-Risk Dyads

VLBW/Preterm Dyads

The overall regression model of parent distress, time spent in asymmetrical co-regulation, and their interaction among medically at-risk VLBW/preterm dyads was significant, *F*(3, 31) = 8.40, *p* < .001, and accounted for 45% of the variance in total child problems in the preschool period. Although asymmetrical co-regulation did *not* emerge as a significant predictor, *b* = 222.58, *t*(31) = 1.62, *p* = .12, 95% CI [-58.19, 503.35], parent distress, *b* = 1.26. *t*(31) = 4.40, *p* < .01, 95% CI [0.67, 1.84] and its interaction with asymmetrical co-regulation, *b* = -11.53, *t*(31) = -2.14, *p* < .05, 95% CI [-22.53, -0.52] were both significant. Among VLBW/preterm dyads, parent distress was positively associated with total child problems when they engaged in *low, b* = 1.22, *t*(31) = 4.48, *p* < .001, 95% CI [0.66, 1.77] and *average, b* = .73, *t*(31) = 4.07, *p* < .001, 95% CI [0.36, 1.10] amounts of time in asymmetrical co-regulation (see Figure 2a). When dyads engaged in asymmetrical co-regulation at most 6.8% of the time, parent distress and child total problems were positively related, *t*(31) = 1.73, *p* = .05, *b* = .47, 95% CI [0.00, 0.94], and this relationship strengthened as time spent in asymmetrical co-regulation decreased.

When parent-child dysfunction, time spent unengaged, and their interaction were entered as predictors, the overall regression model was significant, $F(3, 31) = 7.45$, $p < .001$ and accounted for 42% of the variance in VLBW/preterm children's externalizing problems. Parent-child dysfunction, $b = 1.10$. $t(31) = 4.50$, $p < .001$, 95% CI [0.60, 1.60], unengaged co-regulation, $b = 438.71$, $t(31) = 2.33$, $p < .05$, 95% CI [54.80, 822.62], and their interaction, $b = -27.33$, $t(31) = -2.77$, $p < .01$, 95% CI [-47.47, -7.19] were significant. Importantly, parent-child dysfunction was positively associated with child externalizing problems only when dyads engaged in *low,* $b = 1.10$, $t(31) = 4.50$, $p < .001$, 95% CI [0.60, 1.60] and *average,* $b = .72$, $t(31) = 3.33$, $p < .01$, 95% CI [0.28, 1.16] levels of unengaged co-regulation (see Figure 2b). More specifically, those who spent at most 2.3% of the time in unengaged showed a positive association between parent-child dysfunction and child externalizing problems, $t(31) = 2.04$, $p = .05$, $b = .49$, 95% CI [0.00, 0.97], and this association became more positive with less time spent unengaged.

Psycho-Socially At-Risk Dyads

Similarly for psycho-socially at-risk dyads, the overall regression model of parent distress, time spent in asymmetrical co-regulation, and their interaction was significant, $F(3, 37) = 4.97$, $p < .01$) and accounted for 29% of the variance in preschool-aged children's total problems. Parent distress, $b = .74$, $t(37) = 3.36$, $p < .01$, 95% CI [0.29, 1.19], asymmetrical co-regulation, $b = 414.29$, $t(37) = 3.16$, $p < .01$, 95% CI [149.02, 679.56], and their interaction, $b = -19.82$, $t(37) = -3.31$, $p < .01$, 95% CI [-3196, -7.68] were significant. Only psycho-socially at-risk dyads who spent *low* amounts of time in asymmetrical co-regulation showed a positive association between parent stress and total child problems in the preschool period, $b = .74$, $t(37) = 3.36$, $p < .01$, 95% CI [0.29, 1.19]; see Figure 3a. More specifically, this association emerged

among dyads who spent at most 1.78% of the time in asymmetrical co-regulation, b = .39, t(37) = 2.03, p = .05, 95% CI [0.00. 0.78], and the association strengthened as dyads spent less time in asymmetrical co-regulation.

When parenting distress, time spent in symmetrical co-regulation, and their interaction were entered as predictors for the psycho-socially at-risk group, the overall regression model trended towards significance, F(3, 37) = 2.84, p = .051 and accounted for 19% of the variance in preschool-aged children's externalizing problems. Parent distress, b = -7.88. t(37) = -2.13, p < .05, 95% CI [-15.35, -0.41], symmetrical co-regulation, b = -195.89, t(37) = -2.36, p < .05, 95% CI [-363.87, -27.91], and their interaction, b = 8.86, t(37) = 2.24, p < .05, 95% CI [0.86, 16.86] were significant. Contrary to the findings on asymmetrical interactions, only dyads who engaged in *high* levels of symmetrical co-regulation showed a significant relationship whereby parent distress predicted more externalizing problems in children, b = .85, t(37) = 2.85, p < .01, 95% CI [0.24, 1.45]; see Figure 3b. This association emerged among dyads who spent at least 93.8% of the time in symmetrical co-regulation, t(37) = 2.03, p = .05, b = .43, 95% CI [0.00, 0.86] and strengthened as they spent more time in symmetrical co-regulation.

The overall regression model that included parent-child dysfunction, time spent in unilateral co-regulation, and their interaction as predictors was significant, F(3, 37) = 5.42, p < .01 and accounted for 31% of the variance in preschool-aged children's externalizing problems. Parent-child dysfunction, b = 1.50, t(37) = 4.00, p < .001, 95% CI([0.74, 2.27], unilateral co-regulation, b = 330.99, t(37) = 2.26, p < .05, 95% CI [34.25, 627.73], and their interaction, b = -18.08, t(37) = -2.11, p < .05, 95% CI [-35.43, -0.73] were each significant. Similar to other asynchronous patterns of co-regulation, only dyads who spent *low,* b = 1.50, t(37) = 4.00, p < .001, 95% CI [0.74, 2.27] and *average,* b = .81, t(37) = 2.56, p < .05, 95% CI [0.17, 1.45]

amounts of time in unilateral co-regulation showed a positive association between parent-child dysfunction and externalizing problems in children (see Figure 3c). This association occurred for psycho-socially at-risk dyads who spent at most 4.5% of the time in unilateral co-regulation, $t(37) = 2.03$, $p = .05$, $b = .69$, 95% CI [0.00, 1.38] and strengthened with less time spent in unilateral co-regulation.

Objective 3: Moderating Effect of Co-Regulation in the Association Between Parenting Stress and Later Child Mental Health in Psycho-Socially At-Risk Dyads

The moderating effects of mother-child co-regulation at 4.5-years of age on parenting stress and child externalizing problems, specifically, in psycho-socially at-risk dyads remained when longitudinally predicting to child mental health outcomes at 7-years of age. For the following analyses, all predictors (sub-scales of parenting stress and time spent in patterns of co-regulation) were collected when children were 4.5-years old (T1), and outcomes (child externalizing problems) were collected when children were 7-years old (T2).

Similar to the concurrent findings at T1, the overall longitudinal regression model with parent distress, time spent in asymmetrical co-regulation and their interaction at T1 was significant, $F(3, 29) = 4.59$, $p < .01$ and accounted for 32% of the variance in later child externalizing problems (T2). Parent distress, $b = .68$, $t(29) = 3.01$, $p < .01$, 95% CI (0.22, 1.13), asymmetrical co-regulation, $b = 445.80$, $t(29) = 3.30$, $p < .01$, 95% CI [169.72, 721.89], and their interaction, $b = -19.91$, $t(29) = -3.28$, $p < .01$, 95% CI [-32.34, -7.49] at T1 were significantly associated with child externalizing problems at T2. More parenting distress at T1 predicted more child externalizing problems at T2 only when psycho-socially at-risk dyads spent *low* amounts of time in asymmetrical coregulation, $b = .68$, $t(29) = 3.01$, $p < .01$, 95% CI [00.22, 1.13], see Figure 4a. More specifically, the association between parent distress and later child externalizing

symptoms occurred only when dyads spent at most 1.4% of the time in asymmetrical co-regulation, $t(29) = 2.04$, $p = .05$, $b = .40$, 95% CI [0.00, 0.81] and this association strengthened with less time spent in asymmetrical co-regulation.

The overall longitudinal regression model with parent distress, symmetrical co-regulation, and their interaction at T1 entered as predictors was also significant, $F(3, 29) = 3.69$, $p < .05$ and accounted for 28% of the variance in later child externalizing problems at T2. Parent distress, $b = -8.94$, $t(29) = -2.45$, $p < .05$, 95% CI [-16.40, -1.49], and symmetrical co-regulation, $b = -236.28$, $t(29) = -2.88$, $p < .01$, 95% CI [-404.07, -68.49], and their interaction, $b = 10.01$, $t(29) = 2.56$, $p < .05$, 95% CI [2.01, 18.02] at T1 were significant. Again, contrary to asynchronous patterns of interactions, only psycho-socially at-risk dyads who spent *high* amounts of time in symmetrical co-regulation at T1 showed a significant positive association between parent distress (T1) and later child externalizing problems (T2), $b = .89$, $t(29) = 3.07$, $p < .01$, 95% CI [0.30, 1.48], see Figure 4b. That is, higher parenting distress was associated with more child externalizing problems in later childhood among dyads who spent at least 94% of the time in symmetrical co-regulation in earlier childhood, $t(29) = 2.05$, $p = .05$, $b = .42$, 95% CI [0.00, 0.85], and this association strengthened with more time spent in symmetrical co-regulation.

Similarly, the overall longitudinal regression model with parent-child dysfunction, time spent in symmetrical co-regulation, and their interaction at T1 entered as predictors was significant, $F(3, 29) = 3.36$, $p < .05$ and accounted for 26% of the variance in child externalizing problems at T2. Parent-child dysfunction, $b = -16.62$, $t(29) = -2.23$, $p < .05$, 95% CI [-31.83, -1.41], symmetrical co-regulation, $b = -326.71$, $t(29) = -2.55$, $p < .05$, 95% CI [-588.43, -64.99], and their interaction, $b = 18.22$, $t(29) = 2.31$, $p < .05$, 95% CI [2.12, 34.33] at T1 were each

significant. As parent-child dysfunction in the preschool period increased, so too did child externalizing problems in middle childhood among psycho-socially at-risk dyads who spent *high* amounts of time in symmetrical co-regulation at 4-years of age, $b = 1.27$, $t(29) = 2.95$, $p < .01$, 95% CI [0.39, 2.15], see Figure 4c. More specifically, dyads who spent at least 95% of the time in symmetrical co-regulation showed this positive association between parent-child dysfunction and later child externalizing problems, $t(29) = 2.05$, $p = .05$, $b = .63$, 95% CI [0.00, 1.27], and this association strengthened as time spent in symmetrical co-regulation increased.

Discussion

In the current study, we examined the role of mother-child co-regulation in the association between parenting stress and child mental health in preschool and middle childhood in low- and at-risk groups. Our hypotheses were supported by the findings showing that certain observed patterns of co-regulation moderated the association between parenting stress (namely mother-reported parent distress and parent-child dysfunction) and concurrent internalizing and externalizing problems. Importantly, the interaction between co-regulation and parent stress varied across low- and at-risk groups. Furthermore, within the psycho-socially at-risk group, the findings remained when children were 7-years old. These highlight the nuances of how co-regulation interacts with both parent and broader contextual risk factors in the development of internalizing and externalizing problems in children.

The first objective was to examine the moderating effect of mother-child co-regulation on the association between parenting stress and child mental health in low-risk, full-term dyads. Consistent with our hypothesis, less reciprocal, asymmetrical patterns of co-regulation had a risky moderating effect on child mental health. Specifically, mothers who reported higher levels of distress associated with parenting had children with more internalizing symptoms when they

engaged in asymmetrical co-regulation at least 1.55% of the time. Our results build on previous findings in infancy research showing that interactions lacking in reciprocity, such as in asymmetrical co-regulation, serve as a risk factor for child outcomes (Evans & Porter, 2009). While research in infancy has primarily focused on attachment and infant cognitive development (Evans & Porter, 2009), results from our study focused on children's social-emotional development, in the form of symptoms commonly associated with internalizing symptoms in preschool, such as symptoms of depression and anxiety. Unsurprisingly, asymmetrical co-regulation appeared to exacerbate the established relationship between parenting stress and child internalizing problems (Anthony et al., 2005) in these low-risk dyads. Furthermore, parenting stress has previously been associated with less sensitive and more hostile and authoritarian forms of parenting (Carapito et al., 2020b), which may appear in the form of asymmetrical interactions and further intensify children's problems. Over time, this pattern of interaction may cause children to feel that their wants are unheard leading them to become more passive during exchanges with parents and internalize their problems. Our findings also suggest that associations between parenting stress and child outcomes are complex and cannot be simplified to a dichotomy of good and bad forms of co-regulation across all backgrounds.

As such, our second objective explored the moderating effect of co-regulation on the association between parenting stress and child mental health in at-risk mother-child dyads, namely medically at-risk (VLBW/preterm) and psycho-socially at-risk dyads. Interestingly, the moderating effect of co-regulation patterns were the opposite of our original hypotheses, countering a one-size-fits-all approach to the study of co-regulation. In both VLBW/preterm and psycho-socially at-risk groups, less reciprocal and less engaged interactions had a protective moderating effect on the association between parenting stress and child mental health. In both

groups of at-risk dyads' mothers who reported higher levels of parenting distress had children with increased total problems when they spent low to average amounts of time in asymmetrical co-regulation. In VLBW/preterm dyads, specifically, children's externalizing problems increased when they spent low to average amounts of time unengaged from their mothers, who reported higher levels of parent-child dysfunction. Among psycho-socially at-risk dyads, children were reported to have more externalizing problems when they engaged in low to average levels of unilateral co-regulation with their mothers who also reported higher levels of parent-child dysfunction. Conversely, in this psycho-socially at-risk group, child externalizing problems increased as parent distress increased when they spent high amounts of time in the more engaged and reciprocal symmetrical pattern of co-regulation. Although opposite of our expectations, our findings in at-risk groups provide a nuanced understanding of co-regulation. Specifically, they suggest that, under certain difficult circumstances when the effects of parenting stress may be exacerbated by other situational factors, disengagement from interactions by one or both members of the dyad may be protective. It is possible that these less reciprocal forms of co-regulation prevent the passing of stress from parent to child, thus reducing the association between parenting stress and child mental health difficulties. Thus, researchers may want to move away from the question of which form of co-regulation is adaptive to a question of which form of co-regulation is adaptive when the dyad lives in specific adverse circumstances or under conditions of risk.

One of these adverse circumstances highlighted by our study is the birth of VLBW/preterm children. Previous research has repeatedly found that mothers, especially highly stressed mothers, tend to interact more intrusively and less sensitively with their VLBW/preterm infants (Agostini et al., 2014; Forcada-Guex et al., 2011; Udry-Jørgensen et al., 2011).

Reciprocating these styles of interaction may lead to growing tensions in the dyad over time. Thus, while it may be adaptive and more emotionally safe for low-risk dyads to engage and reciprocate interactions, our findings suggest that this is not the case for at-risk dyads. In other words, engaging in, and contributing to, intrusive interactions, characterized by dysfunction, may exacerbate externalizing problems in childhood among VLBW/preterm dyads.

Another adverse circumstance involves psycho-socially at-risk families. In our study, engaged and reciprocal forms of co-regulation had a risky moderating effect on the relationship between parent stress and child mental health in this at-risk group. Furthermore, less engaged and less reciprocal (i.e., asymmetrical and unilateral) forms of co-regulation had a protective moderating effect on that same relationship. These findings can be explained by the complex relationship dynamics that occur in at-risk dyads. While mothers in VLBW/preterm dyads have been shown to engage more intrusively with their children (Agostini et al., 2014; Forcada-Guex et al., 2011; Udry-Jørgensen et al., 2011), psycho-socially at-risk mothers with childhood histories of aggression and social withdrawal have been shown to exhibit higher levels of hostility towards their preschool-aged children (Stack et al., 2012). In the latter group in the same study, lower levels of parenting stress were associated with more positive mother-child relationships (Stack et al., 2012). Again, our results highlight how the link between parenting stress and child problems (externalizing and total problems on the CBCL) depends on how the dyad co-regulates their interactions and may differ between low- and at-risk groups. Perhaps because of increased risk factors within the dyad, in their environment, and throughout their relationship history, disengagement from their interactions plays a protective role, not seen in the low-risk groups. Importantly, engaging in symmetrical co-regulation does *not* mean that both interactive partners agree. They are simply both engaged and contributing to the ongoing

interaction in a regulated manner. However, a stressed parent in an at-risk group may feel overwhelmed and perceive even co-regulated disagreements as problematic and their child as noncompliant, potentially inflating their reports of child externalizing behaviors.

Our third objective explored the longitudinal moderating effect of co-regulation on the association between parenting stress and later child mental health outcomes in the psycho-socially at-risk group. Consistent with the concurrent findings from when these children were 4.5 years old, dyads who engaged in high levels of symmetrical co-regulation at that time (T1) showed a significant positive association between parent distress and parent-child dysfunction (T1) and later child externalizing problems at 7 years of age (T2). Conversely, dyads who engaged in low levels of asymmetrical co-regulation at T1 showed a significant positive association between parenting distress at T1 and child externalizing problems at T2. Our findings highlight the pervasive influence of parenting stress and co-regulation over time in psycho-socially at-risk populations. These findings on the longer-term implications of parent-child co-regulation are consistent with results from other longitudinal studies showing that parenting stress and styles of interaction influence outcomes across development (Hentges et al., 2019; Kemmis-Riggs et al., 2020; Steele & Mckinney, 2018). For example, Hentges et al. (2019) found that prenatal and postnatal parent stress predicted child internalizing and externalizing problems at 5 years of age via hostile parenting styles and child temperament. In their longitudinal study from early to middle childhood, Kemmis-Riggs et al. (2020) found that hostile parenting and low SES predicted increasing internalizing symptoms in children over time. Stretching further into development, Steele and Mckinney (2018) found evidence that authoritative parenting, coupled with high parent-child relationship quality predicted less internalizing and externalizing problems in adulthood, indicating that the potential implications of parent-child interactions

extend well beyond childhood and warrant further study. Notably, our findings uniquely highlight the longitudinal role of dyadic interactions in socio-emotional development.

Taken together, our results make an important contribution to the study of co-regulation by highlighting the nuances of co-regulation in at-risk mother-child dyads. By considering the moderating effects of co-regulation in both low- and at-risk families, our findings move beyond a rigid dichotomous understanding of patterns of co-regulation as being positive or negative, to consider how asynchronous patterns of interactions can be protective in specific at-risk situations. This is consistent with Sameroff's (2009) theory of transactions, which are constantly occurring both between members of the dyad and their larger environment. While reciprocal, engaged interactions may protect low-risk dyads from the association between parenting stress and child mental health problems, the same is not necessarily true for medically and psycho-socially at-risk dyads who, studies have shown, have very different relationship experiences (Agostini et al., 2014; Forcada-Guex et al., 2011; Stack et al., 2012; Udry-Jørgensen et al., 2011). These differing experiences may lead to and necessitate different styles of interaction between mothers and their children.

Limitations and Future Directions

Our results shed light on how co-regulation moderates the associations between parent stress and child mental health in preschool and middle childhood, in low- and at-risk dyads. In taking a dyadic approach to examining patterns of co-regulation, these findings address important gaps in the literature. However, there are limitations to our study that must be acknowledged to further our understanding.

First, our sample size for each group was relatively low, limiting our power to detect significant effects. To overcome this problem, we limited the number of predictors (excluding

potential controls) to maximize power. As such, the results provide an overall understanding of how the association between parenting stress and child mental health changes across different patterns and levels of co-regulation, but it did not allow for a more detailed understanding of how demographic factors could impact those effects. Future research using larger sample sizes that account for these variables would shed further light on the role of co-regulation in children's social-emotional development. Furthermore, longer periods of observation, across different contexts, and beyond free play interactions, may create more variability in the patterns of co-regulation that emerge within dyads.

Likewise, studies would benefit from exploring children's interactions with other dyadic partners, including other caregivers, siblings, and friends, as these relationships have important implications for child outcomes. For example, McElwain and Volling (2005) found that siblings engaged in more asymmetrical interactions than with their friends in preschool. They also noted that quality sibling and friend relationships were associated with less disruptive behaviors and negativity (McElwain & Volling, 2005; Pike et al., 2005). Furthermore, interaction styles between siblings predicted the quality of their relationship (Howe & Recchia, 2005) and interactions between friends in childhood predicted quality of sibling relationships in adolescence (Kramer & Kowal, 2005). These studies point to the complex, bidirectional nature of relationships. Just as interactive behaviors between mothers and children influence one another, so too does each dyadic partners' relationship history. Thus, understanding how multiple types of relationships are co-regulated is necessary toward developing a deeper understanding of the constantly evolving dyadic process and social-emotional development.

Additionally, our study relied largely on mother report of their own parenting stress and their child's internalizing and externalizing problems. Importantly, however, our study also included

observations of the mother-child dyads, thus our findings were not based solely on questionnaire data. While certainly subjective, numerous studies have supported the use of mother reports when exploring children's mental health, especially by early childhood, and despite mothers' own psychopathology (Olino et al., 2021). That being the case, there is also research indicating that mothers may overlook internalizing symptoms in young children, as these tend to be less noticeable, than externalizing symptoms (Van der Ende et al., 2012). This discrepancy could account for the lack of findings on internalizing symptoms in our at-risk groups, despite the literature on associations between parenting stress, parenting styles, and child internalizing symptoms (Edwards & Hans, 2015; Hentges et al., 2019; Mills et al., 2012; Steenhoff et al., 2021). As research on co-regulation moves into later childhood and adolescence, reports on child mental health from multiple sources, including parents, children, and teachers will help to better understand the role of co-regulation in the association between parenting stress and child internalizing problems.

To the authors' knowledge, this was the first study on co-regulation of interactions in the preschool period, thus we purposely chose conservative risk groups. Our VLBW/preterm group included only healthy dyads who were screened for medical and psycho-social conditions outside of their VLBW/preterm status. Likewise, our psycho-socially at-risk group did not differ significantly on most demographic measures from our low-risk full-term group (except for fewer years of maternal education). Rather, their risk stemmed from the childhood risk histories of the mothers, who were recruited from schools serving low-income neighborhoods. While this psycho-socially at-risk group largely focused on the risk of mothers, we must consider the growing body of research supporting the intergenerational transfer of risk from parent to child (Schoon & Melis, 2019). Despite these conservative groupings, important differences in the way

patterns of co-regulation interacted with parenting stress to predict child outcomes emerged. By first focusing on conservative groups, we can more confidently affiliate these differences with the dyads' VBLW/preterm and psycho-social risk statuses. While our study only examined the *longitudinal* moderating effect of co-regulation in the psycho-socially at-risk group, further research should explore if and how the effect occurs in other low- and at-risk dyads. In their longitudinal study, Faure et al. (2017) found preterm infants whose mothers showed more sensitivity during interactions in infancy experienced fewer internalizing problems in adolescence. Likewise, parenting stress in early childhood has been shown to predict child stress in later years (Kujawa et al., 2020). However, more dyadic research is needed to better understand the moderating effect of co-regulation in families of different backgrounds and risks statuses beyond infancy and childhood. Future studies will also benefit from adding risk considerations (e.g., medical conditions beyond VLBW/preterm status, lower SES groups) and ages (e.g., adolescence) to expand our understanding of co-regulation in adverse circumstances.

Conclusions

Together, our findings point to the complex nature of co-regulation and the role it plays in social-emotional development, including well into early and middle childhood. Importantly, time spent in specific patterns of co-regulation interacted with parenting stress, namely parent distress and parent-child dysfunction, to predict externalizing and, to a lesser extent, internalizing problems in preschool-aged children. Interestingly, the moderating effect of these patterns of co-regulation differed across low- and at-risk groups, supporting the notion that co-regulation is not a one-size-fits-all approach. Among low-risk mother-child dyads, asynchronous styles of co-regulation acted as a risk factor by strengthening the association between parent distress and child internalizing problems. The opposite was true for both at-risk groups (VLBW/preterm and

psycho-socially at-risk), whereby asynchronous patterns of co-regulation buffered against the association between parenting stress and total and externalizing problems. Furthermore, more time spent in engaged and reciprocal forms of co-regulation exacerbated the association between parent stress and disruptive problems in children in psycho-socially at-risk dyads. Importantly, these findings extended into middle childhood within the psycho-socially at-risk group, indicating long-term implications of the way mothers and children co-regulate their interactions.

The results from our study add to the growing literature on co-regulation by extending our observations and analyses past infancy and into early and middle childhood using a dyadic approach and systematic observational coding. They also highlight the importance of understanding how broader contextual factors, such as risk status and parenting stress, uniquely interact with co-regulation to predict child outcomes. Our study takes us beyond the assumption of a dichotomous view of co-regulation, whereby some patterns are deemed adaptive and others maladaptive to a more nuanced understanding of what pattern is adaptive under certain circumstances in certain dyads. In doing so, it supports both Sameroff's (2009) theory of transactions occurring between child, mother, and environment, as well as Fogel's (1993) dynamic understanding of interactions as constantly changing and evolving. These findings have important implications for the development and fostering of healthy relationships and social-emotional wellbeing in children and families, as well as parenting practices and dynamics.

Table 1

Demographic and Medical Characteristics of Full-Term, VLBW/Preterm (PT), and Psycho-Socially At-Risk (PSR) Dyads

	Fullterm (n = 27)		VLBW/PT (n = 36)		PSR (n = 42)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Child age at T1 (years)	4.63	0.40	4.95	0.71	4.64	0.49
Child age at T2 (years)	--	--	--	--	7.65	0.62
Infant gestation (weeks)***	39.44	0.97	28.56	2.55	39.88	1.47
Infant birth weight (g)***	3510.63	361.40	1100.47	252.03	3490.90	487.73
Maternal age (years)**	34.04	5.35	38.19	5.14	33.36	3.42
Maternal education**	15.00	2.18	14.19	3.12	13.07	2.07
Maternal occupational prestige	442.15	181.16	374.58	159.64	377.36	125.26
	Fullterm (*n* = 27)		VLBW/PT (*n* = 36)		PSR (*n* = 42)	
	% of *n*	*n*	% of *n*	*n*	% of *n*	*n*
Sex of child						
Female	51.90	14.00	47.20	17.00	59.50	25.00
Male	48.10	13.00	52.80	19.00	40.50	17.00
Birth order						
First born	63.00	17.00	44.40	16.00	47.60	20.00
Second born	25.90	7.00	30.60	11.00	40.50	17.00
Third born	3.70	1.00	22.20	8.00	7.10	3.00
Fourth born	7.40	2.00	2.80	1.00	4.80	2.00
Family Unit						
2-parent Household	88.90	24.00	88.90	32.00	95.24	40.00
1-parent Household	11.10	3.00	11.10	4.00	4.76	2.00
Maternal ethnic origin						
White	88.90	24.00	77.80	28.00	100.00	42.00
Black	3.70	1.00	11.10	4.00	0.00	0.00
Asian	3.70	1.00	2.80	1.00	0.00	0.00
Middle Eastern	0.00	0.00	2.80	1.00	0.00	0.00
Hispanic	3.70	1.00	5.60	2.00	0.00	0.00

Note. Mean differences between groups were evaluated using ANOVAs. Ages of VLBW/preterm children were adjusted for prematurity

$p < .05$, $^{**}p < .01$, $^{***}p < 0.001$ (two-tailed).

$n = 30$ for PSR at 7 years of age.

Table 2

Descriptive Statistics for Patterns of Co-Regulation, Parenting Stress (PSI), and Child Behavior Problems (CBCL)

Variable	Full-term (n = 27)		VLBW/PT (n = 36)		PSR (n = 42)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Co-Regulation						
Symmetrical	0.92	0.06	0.90	0.07	0.92	0.06
Asymmetrical	0.04	0.03	0.04	0.04	0.02	0.04
Unilateral	0.03	0.04	0.04	0.04	0.04	0.04
Unengaged	0.01	0.02	0.02	0.02	0.02	0.02
Disruption	0.001	0.003	0.003	0.01	0.002	0.005
Parenting Stress (PSI)						
Parent Distress	21.67	8.12	24.94	8.21	22.79	7.48
Parent-Child Dysfunction	14.67	1.94	18.14	6.19	17.07	4.83
Difficult Child	25.44	5.71	27.23	9.18	25.79	5.28
Total Stress	61.78	12.94	70.31	21.19	65.64	14.42
Child Problems (CBCL)						
Internalizing Problems	50.37	8.63	48.46	9.46	49.40 (50.42)	8.37 (8.91)
Externalizing Problems	52.63	9.34	50.63	9.64	51.93 (53.00)	10.35 (9.81)
Total Problems	52.59	9.48	50.23	10.84	51.02 (50.69)	10.08 (9.72)

Note. Parentheses indicate descriptive information at 7-years of age for PSR dyads (n = 36).

Table 3

Correlations Between Types of Co-Regulation, Parenting Stress (PSI), and Child Behavior Problems (CBCL)

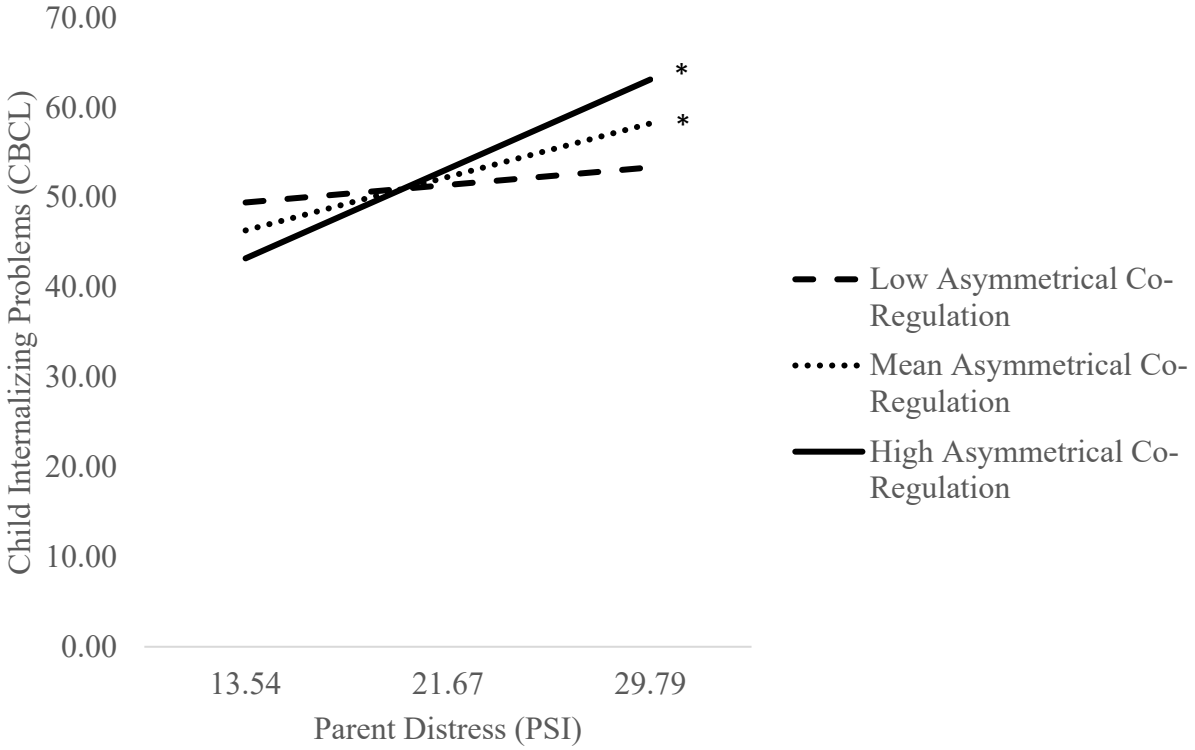
	Co-Regulation					Parenting Stress				Child Problems (4-years)			Child Problems (7-years)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Co-Regulation															
1. Symmetrical	1.00														
2. Asymmetrical	-0.68**	1.00													
3. Unilateral	-0.73**	0.13	1.00												
4. Unengaged	-0.34**	-0.10	0.13	1.00											
5. Disruption	-0.21*	0.15	0.09	-0.15	1.00										
Parenting Stress															
6. Parent Distress	0.07	-0.05	-0.07	-0.10	0.20*	1.00									
7. Parent-Child Dysfunction	0.05	-0.07	-0.04	-0.11	0.39**	0.51**	1.00								
8. Difficult Child	0.14	-0.11	-0.08	-0.16	0.27**	0.60**	0.63**	1.00							
9. Total Stress	0.11	-0.09	-0.08	-0.14	0.32**	0.87**	0.79**	0.88**	1.00						
Child Problems (4-years)															
10. Internalizing Problems	0.21*	-0.16	-0.12	-0.16	0.10	0.40**	0.30**	0.54**	0.50**	1.00					
11. Externalizing Problems	0.16	-0.08	-0.15	-0.10	0.09	0.36**	0.42**	0.68**	0.57**	0.71**	1.00				
12. Total Problems	0.22*	-0.15	-0.19	-0.13	0.12	0.39**	0.43**	0.66**	0.58**	0.85**	0.92**	1.00			
Child Problems (7-years)															
13. Internalizing Problems	0.04	-0.01	-0.07	-0.13	0.46**	0.20	0.39*	0.32	0.35*	0.40*	0.39*	0.52**	1.00		
14. Externalizing Problems	-0.18	0.09	0.24	-0.10	0.11	0.28	0.28	0.60**	0.45**	0.52**	0.68**	0.62**	0.51**	1.00	
15. Total Problems	-0.15	0.08	0.18	-0.17	0.36*	0.31	0.44*	0.59**	0.51**	0.56**	0.70**	0.74**	0.82**	0.85**	1.00

Note. Child Problems at 7-years is for PSR group only (13-15).

*$p < .05$, **$p < .01$, ***$p < .001$.

Figure 1

The Moderating Effect of Asymmetrical Co-Regulation on the Association between Parent Distress (PSI) and Child Internalizing Problems (CBCL) in Low-Risk Full-Term Dyads



Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 2

The Moderating Effect of Co-Regulation on the Association between Parenting Stress (PSI) and Child Problems (CBCL) in VLBW/Preterm Dyads

Figure 2a: Asymmetrical co-regulation

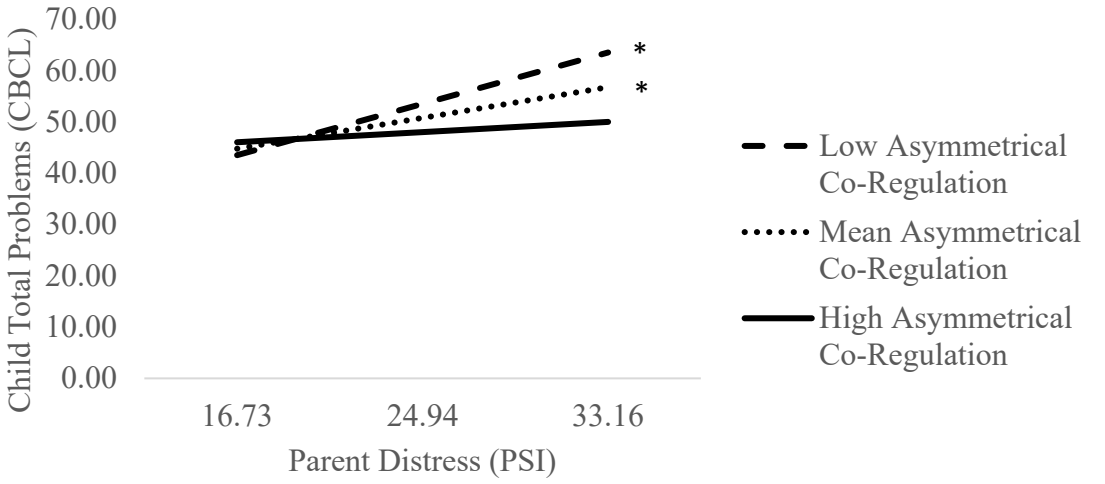
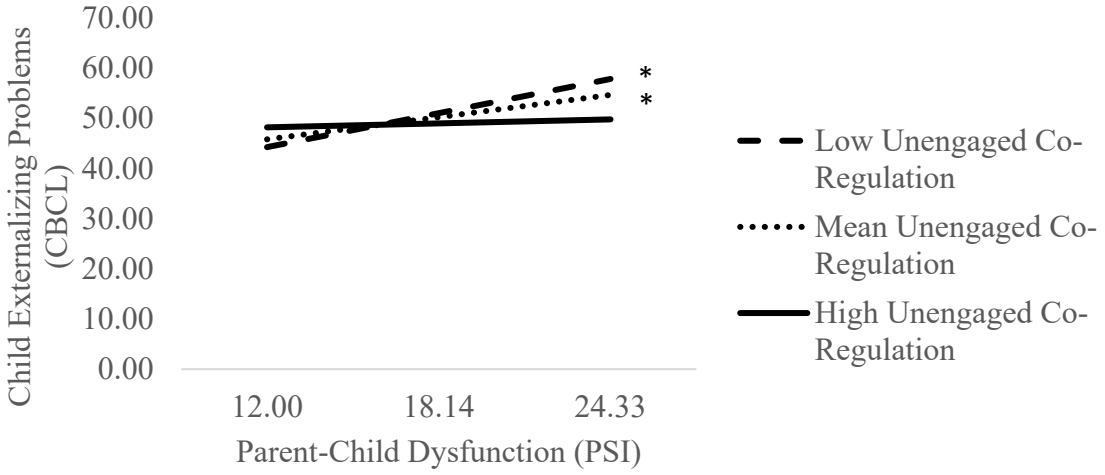


Figure 2b: Unengaged co-regulation



Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 3

The Moderating Effect of Co-Regulation on the Association between Parenting Stress (PSI) and Child Problems (CBCL) in Psycho-Socially At-Risk Dyads

Figure 3a: Asymmetrical co-regulation

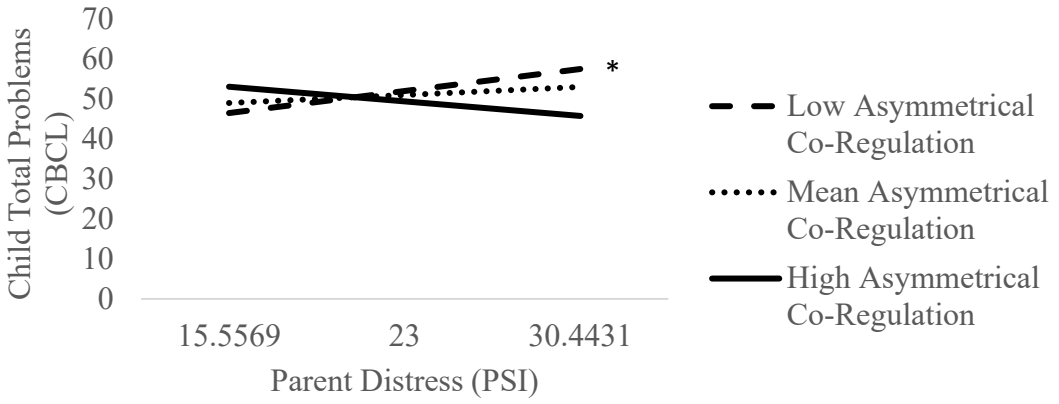


Figure 3b: Symmetrical co-regulation

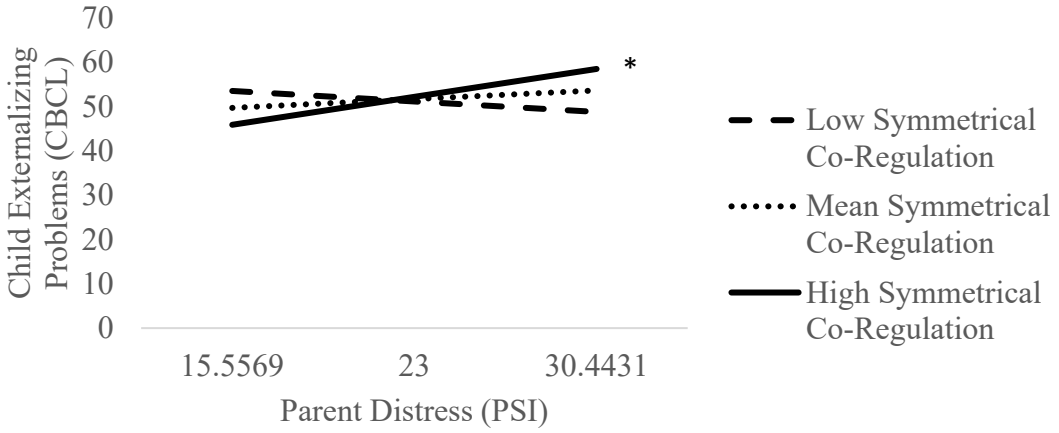
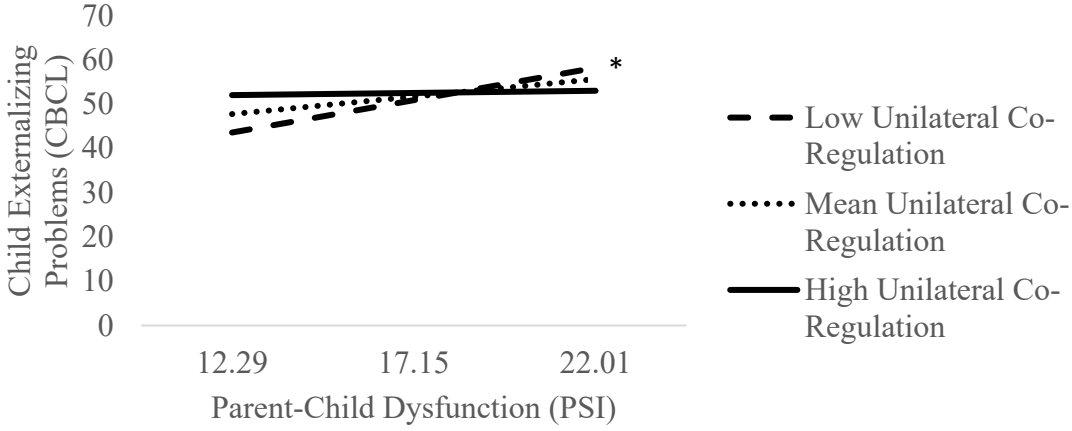


Figure 3c: Unilateral co-regulation



Note. *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 4

The Moderating Effect of Co-Regulation on the Longitudinal Association between Parent Distress (PSI) and Child Externalizing Problems (CBCL) in Psycho-Socially At-Risk Dyads

Figure 4a: Asymmetrical co-regulation

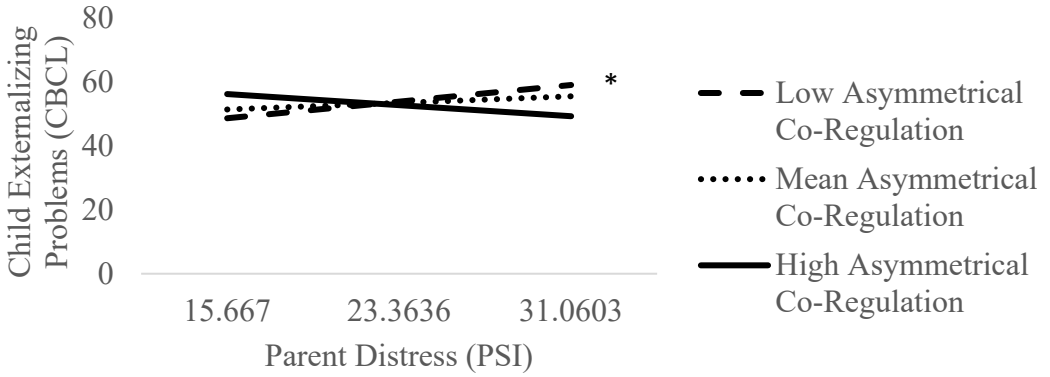


Figure 4b: Symmetrical co-regulation

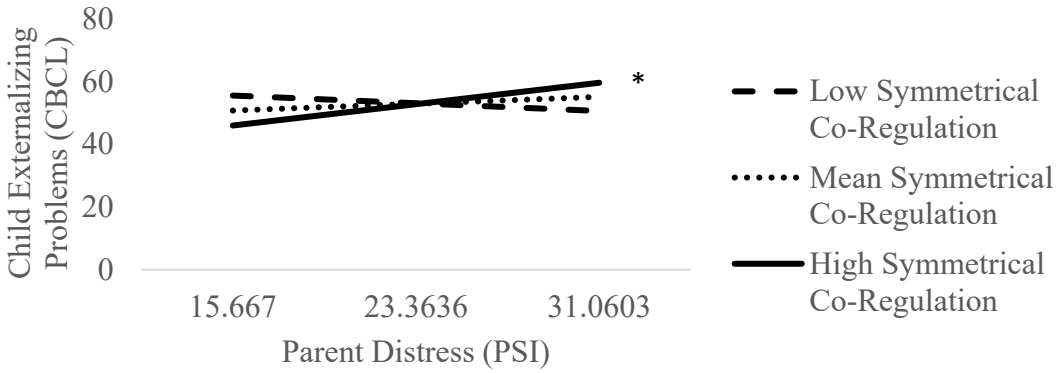
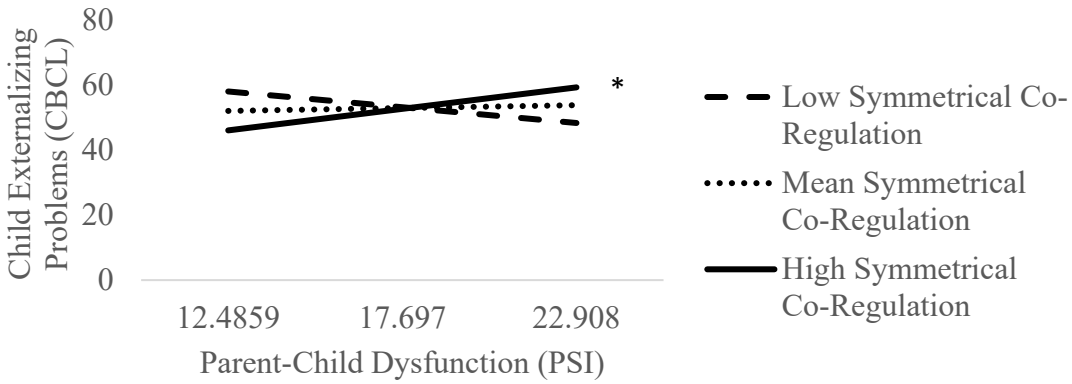


Figure 4c: Symmetrical co-regulation



Note. $*p < .05$, $**p < .01$, $***p < .001$.

Chapter 5: General Discussion

This series of two studies was designed to explore the development of mother-child co-regulation within a Dynamic Systems (Fogel, 1993) and Transactional Model (Sameroff, 2009) framework. The Transactional Model highlights the importance of mutual influences between both the mother and child, as well as their broader environment (Sameroff, 2009). Dynamic Systems Theory takes this holistic approach to studying interactions a step further, noting that interactive behaviors are best understood by studying patterns within the dyads' communication, rather than individual behaviors of each partner as people jointly create meaning in their interactions (Fogel, 1993). To capture co-regulation from a Dynamic Systems perspective, Fogel and colleagues (2003) developed the *Revised Relational Coding System* (RRCS), in which patterns of co-regulation are coded dyadically based on the level of engagement and contribution to the interaction from the interactive partners. These patterns range from the mutually sensitive and reciprocal symmetrical pattern to a breakdown of co-regulation leading to emotion dysregulation (disruptive pattern) and complete disengagement between partners (unengaged pattern). In between these extremes are the asymmetrical pattern (both partners are engaged, while one is actively contributing to the interaction) and unilateral pattern (one partner engaged while the other is disengaged; Fogel et al., 2003). Even within this dyadic perspective, Fogel (1993) emphasizes the need to consider broader contextual and historical factors in the dyad's relationship to better understand how they co-regulate their interactions. As such, the findings from the present two studies highlight how different patterns of dyadic co-regulation change over the first 4 years of life, and how risk factors, specifically parenting stress, are associated with those trajectories of co-regulation and interact with co-regulation to predict mental health outcomes in children. Importantly, these findings were explored in the context of differing levels

of medical and psycho-social risk to investigate the influence of broader contextual factors on mother-child co-regulation.

To the author's knowledge, no study to date has examined co-regulation of communication beyond the second year of life. Thus, our understanding of how co-regulation develops is largely limited to infancy and early toddlerhood (Aureli et al., 2018; Aureli & Presaghi, 2010; Doiron & Stack, 2017; Evans & Porter, 2009; Hsu & Fogel, 2001, 2003; Porter et al., 2022; Sansavini et al., 2015). Furthermore, while researchers are increasingly exploring how co-regulation in VLBW/preterm infant-mother dyads differs from full-term dyads (Doiron & Stack, 2017; Sansavini et al., 2015), there continues to be gaps in our understanding of co-regulation in psycho-socially at-risk groups, despite evidence of different parenting styles and interactive behaviors among these families (Briscoe et al., 2017; Carapito et al., 2020; Matte-Gagné et al., 2018; Fonseca et al., 2020; Padilla et al., 2020; Stack et al., 2012, 2017). Our results from Study 1 extend our understanding of how co-regulation develops into early childhood and in different risky contexts (low-risk children born full-term, and at-risk children born VLBW/preterm or to mothers with childhood histories of psycho-social risk). While group differences in co-regulation were only observed at 18-months of age, with psycho-socially at-risk dyads engaging in more asymmetrical co-regulation than full-term and VLBW/preterm groups, further analyses indicated variation in how groups co-regulate their interactions over time. Full-term and VLBW/preterm dyads followed similar, complex trajectories across the first four years in the time they spent in engaged and reciprocal interactions. Their time spent in symmetrical co-regulation decreased from 6- to 12-months, then increased from 12- to 18-months, and increased again (less rapidly) from 18- to 48-months. In contrast, psycho-socially at-risk dyads simply engaged in increasingly more symmetrical interactions over time. Regarding asymmetrical co-

regulation (less reciprocal but still mutually engaged interactions), both at-risk groups initially spent decreasing time in asymmetrical co-regulation over the latter half of the first year, then increasing time from 12- to 18-months. However, while VLBW/preterm dyads continued to spend more time in asymmetrical interactions during the preschool years, their psycho-socially at-risk counterparts began spending more time in this pattern of co-regulation. Both low- and at-risk groups spent increasing amounts of time in unilateral co-regulation over the first year, followed by a sharp decrease from 12- to 18-months, and a continued, gradual decrease from 18-months onward. These findings across the groups were largely consistent with Aureli and Presaghi's (2010) study on a smaller sample of typically developing infants showing an increase in symmetrical and decrease in unilateral co-regulation over the first two years of life. These findings are consistent with Bronson's (2000) assertion that early mother-infant exchanges shape expectations for future interactions. While infants are certainly not passive recipients of maternal efforts at communication (Bronson, 2000), our results suggest that their developing social-emotional capacities over the first 2 years increase their ability to engage in synchronous, co-regulated interactions. Likewise, mothers build more accurate expectations of their unique infants during the first 2 to 4 years, which further facilitates synchronous co-regulation. This is consistent with Dynamic Systems Theory, which posits that mother-child relationships are in constant flux as both mother and child build unique and shared histories and expectations over time and through their interactions (Fogel, 1993). That is, over time, as infants and mothers learn about each other through their relationships, and infants develop more sophisticated social-emotional skills, they spend increasing proportions of time in synchronous patterns of co-regulation.

Interestingly, additional factors including infant sex, maternal education, and parenting stress were associated with changes in co-regulation over time among the VLBW/preterm and psycho-socially at-risk dyads, but not in the low-risk full-term dyads. Specifically, VLBW/preterm girls spent more time in symmetrical interactions with their mothers, while boys with mothers reporting higher levels of parenting distress engaged in more unilateral interactions over time. Surprisingly, mothers of VLBW/preterm infants with greater years of education spent more time in asymmetrical co-regulation. Psycho-socially at-risk dyads showed slightly different patterns from their medically at-risk counterparts. For psycho-socially at-risk dyads, mothers with greater years of education spent less time unengaged from their infants, and higher levels of parenting stress were associated with less asymmetrical co-regulation over time.

Study 2 sought to further understand the association between co-regulation and parenting stress in low- and at-risk dyads and its implications for children's mental health. This study focused primarily on the preschool period (4.5 years of age) because of significant social-cognitive developments that prepare children for the social-emotional challenges that accompany large transitions, such as the transition to school, during that time (Santos et al., 2014). The results of Study 2 showed that co-regulation moderated the association between parenting stress and preschool-aged children's mental health differently across the risk groups. Consistent with our hypotheses that asymmetrical co-regulation would act as a risk factor, parenting distress was associated with more internalizing symptoms in full-term children among dyads who spent high levels of time in asymmetrical co-regulation. Our findings add to the growing body of research reporting less desirable outcomes for dyads who engage in higher levels of asymmetrical co-regulation, including weaker performance on cognitive measures and more insecure parent-child attachment (Evans & Porter, 2009).

Intriguingly, while asymmetrical co-regulation served as an exacerbating risk factor for low-risk dyads, it appeared to buffer the effects of parenting stress in medically and psychosocially at-risk dyads. In both at-risk groups, parent distress was associated with more total child problems (internalizing and externalizing symptoms) when dyads engaged in low levels of asymmetrical co-regulation. Furthermore, psycho-socially at-risk dyads who engaged in low levels of unilateral co-regulation and VLBW/preterm dyads who showed low levels of unengaged interactions showed positive associations between mother-reported parent-child dysfunction and child externalizing symptoms. However, psycho-socially at-risk dyads who spent high levels of time in the more reciprocal, symmetrical pattern of co-regulation, showed a positive association between parent distress and externalizing problems in children. In Study 2, longitudinal support for these findings in middle childhood among the psycho-socially at-risk dyads was also found. Those who spent low amounts of time in asymmetrical co-regulation at 4.5 years of age (T1) showed a positive association between parenting distress at T1 and children's externalizing problems at 7 years of age (T2). Conversely, dyads who spent high levels of time engaged in symmetrical co-regulation at T1 showed a positive association between parenting stress, specifically parent distress and parent-child dysfunction, at T1 and children's externalizing symptoms at T2. Although contrary to our hypotheses and past research demonstrating less favorable outcomes associated with asymmetrical and unilateral co-regulation (Evans & Porter, 2009), these findings speak to broader challenges in the interpretations of mother-child interactions in these at-risk groups and their histories of interactions. Previous research has shown that mothers of VLBW/preterm often interact more intrusively with their infants (Ionio et al., 2017). Meanwhile, mothers with histories of psycho-social risk, specifically those with higher levels of childhood histories of aggression and social withdrawal, have been

shown to exhibit higher levels of hostility towards their children (Stack et al., 2012). Additionally, children in these at-risk groups often struggle with their own self-regulation (August et al., 2017; Jean & Stack, 2012), further complicating interactions with their parents. Thus, efforts by one or both partners to disengage (unilateral) or take a more passive stance (asymmetrical), especially when there are high levels of parent-child dysfunction may be adaptive in these specific contexts. Furthermore, while not assessed directly in this study, past research has suggested that children may internalize worries communicated to them by their parents (Bayer et al., 2006). Moreover, symmetrical co-regulation denotes a pattern of interaction; however, the content of that interaction (e.g., topic of discussion) can vary. It is therefore possible, that these mothers in the at-risk groups communicate their worries in a symmetrical manner to their children, who in turn may internalize those conversations, regardless of whether it is a synchronous interaction.

Taken together, using an observational approach, our results from these two studies highlight how co-regulation develops across the first four years of children's lives for families with typical and more adverse experiences. Furthermore, parenting stress, which is more common amongst mothers with these adverse experiences (Lange et al., 2019; Treyvaud et al., 2014), is both associated with the trajectory of various patterns of co-regulation and interacts with co-regulation differently in low- and at-risk groups to predict child mental health outcomes both concurrently in preschool and longitudinally into middle childhood. This latter finding is extremely important when designing and considering interventions targeting the parent-child relationship, particularly among at-risk families. Past studies have often described symmetrical co-regulation as being associated with more positive outcomes, including infants' cognitive development and mother-infant attachment (Evans & Porter, 2009). While significant, such

studies need to be understood in the context of the relative risk level of their participants. Although our results lend some support to this theory of asynchronous forms of co-regulation being less optimal, such findings were isolated to the low-risk full-term dyads. Conversely, asynchronous co-regulation (particularly, asymmetrical co-regulation) buffered against child internalizing and externalizing symptoms in at-risk dyads. Thus, not only was parenting stress associated with co-regulation over time, but these two variables interacted to predict child mental health outcomes in different ways depending on level of risk. Our results highlight the importance of examining co-regulation from a more nuanced perspective that looks beyond a dichotomy of good and bad forms of interactive patterns to one that considers appropriate fit for specific dyads and their context.

Limitations and Future Directions

While the findings from these two studies expanded our understanding of the development of co-regulation over time and how it interacts with various risk factors, it is important to acknowledge the limitations of these studies and the implications such limitations have for our interpretation and future directions. These limitations include the studies' sample sizes, which were impacted by attrition across time points in data collection, the conservative inclusion criteria of the at-risk groups, exclusive focus on mother-child dyads, limits to the interpretability of the *RRCS* (Fogel et al., 2003) patterns of co-regulation, and use of primarily maternal reports of parenting stress and children's internalizing and externalizing symptoms.

Longitudinal studies commonly suffer from attrition in their samples over time, thus it is unsurprising that our studies also endured this challenge. Over the span of 4 years, the missing data of our total sample ranged from 31-38%. Although the missing data was determined to be completely at random, and efforts were made to impute missing data, when possible (such as in

Study 1), this has implications for the generalizability of the results and it impacted the complexity of analyses that could be run. As a result, potential predictors of the trajectories of different patterns of co-regulation and child mental health problems, including variables such as relationship quality, maternal adverse childhood experiences, and additional socio-economic status variables (Cooke et al., 2019), as well as child temperament (Dalimonte-Merckling & Brophy-Herb, 2019) could not be explored at this time. Importantly, parenting stress, child sex, and maternal education were prioritized as predictors in both studies because of the wealth of literature supporting associations between these variables and mother-child interactions and relationships (Huang et al., 2015; Lovas, 2005; Mackler et al., 2015; Neuhauser, 2018). In addition, although the longitudinal approach in both studies posed challenges, they were the first studies that followed mother-infant co-regulation into early childhood and furthered our understanding of the development and implications of different patterns of mother-infant co-regulation in low- and at-risk groups.

Our studies sought to shed light on how co-regulation develops in the context of risk, specifically, medical (infants born VLBW/preterm) and psycho-social risk (parents from disadvantaged backgrounds). While some researchers have explored co-regulation in VLBW/preterm dyads, these studies were largely limited to the first two years of life (Doiron & Stack, 2017; Sansavini et al., 2015), and the authors were not aware of any studies examining co-regulation of communication in psycho-socially at-risk dyads. Thus, given that this was a novel area of study, at-risk groups followed strict inclusion criteria. In the VLBW/preterm group, dyads with serious medical conditions or whose mothers suffered from mental health difficulties were excluded from the studies. Likewise, the psycho-socially at-risk group consisted of parents who attended schools serving low-income neighborhoods during childhood (Schwartzman et al.,

1985; Serbin et al., 1998; Stack et al., 2017). These inclusion criteria may have decreased the generalizability of our findings, as both risk groups were relatively healthy compared to other VLBW/preterm and psycho-socially at-risk families, who often encounter a wide range of difficulties throughout their development, including congenital medical conditions (Gonçalves et al., 2020), parent mental health difficulties (Hakanen et al., 2019), and poverty (Hall et al., 2019). The inclusion criteria may have also washed-out potential differences in co-regulation, since some variables contributing to their high-risk status were excluded. However, even with these conservative criteria, differences were observed, both in how parenting stress was associated with trajectories of co-regulation over time (Study 1) and how co-regulation interacted with parenting stress to predict child mental health outcomes (Study 2). Adhering to more rigorous criteria facilitated the interpretation of the findings by reducing potential confounds, thus allowing us to attribute these differences and associations specifically to the at-risk dyads' VLBW/preterm or psycho-social risk statuses. This is particularly important given that our sample size limited the number of control variables that could be included in the analyses. Future studies will benefit from gradually increasing the umbrella of risk to further explore the various ways risk factors are associated with co-regulation.

Following in the steps of most research to date on co-regulation of communication (Aureli & Presaghi, 2010; Evans & Porter, 2009; Hsu & Fogel, 2003; Sansavini et al., 2015), our studies focused on interactions between mothers and their infants. While these interactions have been associated with child outcomes in both our Study 2 and work by other researchers (Evans & Porter, 2009), such findings may not generalize to other relationships in children's lives, such as siblings and other caregivers. In fact, previous research has indicated that children interact differently with friends, siblings, and other caregivers, and these relationships also have

significant implications for child outcomes (Howe & Recchia, 2005; Lovas, 2005; McElwain & Volling, 2005). Although these interactions fall outside the scope of the current studies, future research would benefit from expanding their investigations on co-regulation to other types of relationships.

Dynamic Systems Theory emphasizes the importance of examining the dyad as a whole, rather than focusing on discrete behaviors of each individual (Fogel, 1993). Using the *RRCS* (Fogel et al., 2003), which is grounded in Dynamic Systems Theory, allowed us to examine dyadic patterns in this nuanced and holistic manner. However, because interactive patterns are coded rather than behaviors, our interpretation of the findings was limited. In other words, although the coding system allowed us to analyze general patterns in the interaction, it did not address the different roles of each partner in the interaction. For example, during asymmetrical interactions, we did not determine whether the mother or infant were the more active or passive partners. Although beyond the scope of Dynamic Systems Theory, breaking down the interaction in this way could help to understand the mother and child factors that uniquely influence the way they co-regulate their interactions (e.g., does maternal stress predict whether mothers or children are more passive during asymmetrical interactions?). Furthermore, the focus on general interactive patterns overlooked the content of mothers' discussions with their children. It is feasible that mothers and children can engage in symmetrical interactions about developmentally inappropriate or difficult topics (e.g., discussions about adult stresses), and this could have implications for children who internalize these discussions and worries (Bayer et al., 2006). Thus, future research may also benefit from assessing the topic of conversations that occur during co-regulation of communication, while keeping in mind that conversations about

disagreements can occur in a symmetrical manner (i.e., symmetrical co-regulation is not simply matching emotions or discussing topics in a positive manner).

Finally, although the interactions between mothers and their children were observationally coded for co-regulation, additional variables including parenting stress and child internalizing and externalizing symptoms relied solely on maternal reports. While previous research studies have also relied on maternal reports of children's symptoms in early childhood (Olino et al., 2021), there are limitations that should be noted. Maternal reports on children's symptoms and behaviors may be influenced by mothers' own mental health (Najman et al., 2000). Furthermore, internalizing symptoms are generally more difficult to accurately report, particularly in young children who may struggle to articulate their feelings (Van der Ende et al., 2012). Future research exploring associations between co-regulation and child symptoms will benefit from gathering such information from multiple sources.

Clinical Implications and Applications

In addition to contributing to our growing understanding of the development of co-regulation of communication, findings from these two studies have important clinical implications for fostering healthy mother-child relationships. There is an abundance of research demonstrating associations between the parent-child relationship and both child and parent mental health (e.g., Alink et al., 2009; Borji et al., 2018; Kim & Cicchetti, 2004). Studies have repeatedly found that warm, sensitive caregiving is associated with favorable outcomes in children, including emotion regulation, social-cognitive skills, social competence, and language development (Harel et al., 2002; Howes & Hong, 2008; Licata et al., 2013; Little & Carter, 2005; Moreno et al., 2008). However, even from infancy, child factors such as temperament and level of externalizing behaviors bi-directionally impact parenting practices and styles (Kiff et al.,

2011; Sanson et al., 2004). Furthermore, the parent-child relationship develops in the context of various environmental factors (Bronfenbrenner, 1977; Fogel, 1993; Sameroff, 2009), including, but not limited to, socio-economic status, socio-emotional histories of the families, and medical complications. Using a Dynamic Systems approach, understanding the complex interplay of such factors is crucial to understanding how co-regulation develops (Fogel, 1993). According to Fogel (1993), the goal of co-regulation is communication or shared understanding. To do this, interactive partners must be attuned to each other's thoughts and emotions, characteristics of warm and sensitive caregiving, and respond appropriately to each other's social cues (Bronson, 2000; Fogel, 1993).

It is perhaps unsurprising then that interventions targeting a wide range of social-emotional difficulties in childhood target the parent-child relationship (Suldo & Fefer, 2013). In fact, even interventions that focus on externalizing behaviors, such as Parent-Child Interaction Therapy (PCIT) first focus on establishing a warm parent-child relationship by increasing parents' attunement and sensitivity to their children (McNeil & Hembree-Kigin, 2010; Lieneman et al., 2017). Other evidence-based interventions such as emotion coaching in Emotion-Focused therapies guide parents in connecting with children by identifying and validating their feelings (i.e., helping parents to become attuned to their children's emotional experiences; Gottman, 1997). The results from Studies 1 and 2 highlight both the typical progression of co-regulation and its development under adverse circumstances. Our findings suggest that some dyads in such groups may benefit from interventions targeting mother-child attunement, such as those described above, and point to the importance of broader systemic factors in the parent-child relationship, particularly among the at-risk groups.

Although not linear, results from Study 1 indicated that both low- and at-risk groups

engaged in increasingly symmetrical interactions over the first four years of life. This suggests that mother-child dyads generally became more attuned over time during their interactions. Importantly, however, VLBW/preterm boys and their mothers appeared vulnerable to parenting stress, which was associated with more time spent in unilateral interactions. These results point to the importance of closely monitoring maternal mental health, particularly in medically risky contexts, which themselves are very stressful to parents (Forcada-Guex et al., 2011; Rowe & Jones, 2010; Treyvaud et al., 2011, 2014). These mothers and their children may have more difficulties attuning to each other's needs and may warrant early attention and interventions targeting their relationships.

Attunement, however, is more complex than simply increasing symmetrical interactions among medically and psycho-socially at-risk dyads, as was demonstrated in Study 2. While previously considered to be a less adaptive form of co-regulation, resulting in less favorable outcomes for both the infants and their relationships with their mothers (Evans & Porter, 2009), asymmetrical co-regulation had different moderating effects for low- and at-risk dyads. Among low-risk dyads, results were consistent with previous research describing asymmetrical co-regulation as a risk factor. As expected, low-risk dyads who spent more time in asymmetrical co-regulation showed a positive association between parenting stress and internalizing symptoms. However, asymmetrical co-regulation served a protective purpose in VLBW/preterm and psycho-socially at-risk dyads whose mothers reported experiencing more parenting stress. In fact, in both groups of at-risk dyads, those who engaged in low levels of asymmetrical co-regulation showed a positive association between parenting stress and child internalizing and externalizing symptoms in the preschool years. While at first glance, these findings may seem to counter the wealth of evidence in support of attunement and sensitive caregiving (characteristics

of symmetrical co-regulation), it is important to interpret these findings in the context of risk. Considering previous research noting that mothers of preterm infants tend to interact more intrusively with their infants (Muller-Nix et al., 2004; Udry-Jørgensen et al., 2011), one of the dyadic partners taking a more passive stance in interactions may be beneficial to children, especially when mothers are more stressed.

Study 2's findings that lower levels of unengaged interactions in VLBW/preterm dyads and lower levels of unilateral interactions in psycho-socially at-risk dyads also strengthened the association between parenting stress (specifically, parent-child dysfunction) and child externalizing problems further illustrate this point. During social interactions, disengagement of one or both partners may help to de-escalate conflicts in the moment, when people are emotionally dysregulated. This may be particularly pertinent among at-risk children who may struggle more than their low-risk counterparts to regulate their emotions and behaviors (Cheng et al., 2016; Sameroff, 2000; Voigt et al., 2013) and whose parents may experience more adversity and stress (Lange et al., 2019; Mikolajczak et al., 2018; Muller-Nix et al., 2004; Rowe & Jones, 2010; Treyvaud et al., 2011, 2014). As aforementioned, future studies will benefit from exploring the content of these interactions, as well as the general co-regulative patterns, to determine how these asymmetrical, unilateral, and unengaged interactions occur in different contexts.

Our results also point to the growing evidence supporting early interventions in the parent-child relationship. Findings from Study 2 demonstrated that, among psycho-socially at-risk dyads, co-regulation (specifically, less time spent in asymmetrical co-regulation) in the preschool period moderated the association between parenting stress and child externalizing symptoms into middle childhood. This longitudinal finding points to the potential lasting effects of parent-child

co-regulation and emphasizes the need for targeting these interactions early in development. Fortunately, interventions such as emotion coaching and PCIT are adaptable and can target the parent-child relationship in these early years (Johnson et al., 2017; Phillips & Mychailyszyn, 2022). Future research will benefit from looking at these longitudinal implications further in other low- and at-risk groups.

Importantly, these findings should not discourage clinicians from intervening through emotion coaching and building interactive skills; rather, efforts should also be made to address broader systemic factors that may amplify co-regulative difficulties and associated child mental health problems. While interventions such as emotion coaching and PCIT address the moment-to-moment exchanges between parents and children, such micro-level approaches do not address the larger systemic risk factors that many disadvantaged families face. Furthermore, these systemic risk factors often create obstacles to accessing interventions (Weisenmuller & Hilton, 2021). Results from Study 1 showed that psycho-socially at-risk mothers with more years of education spent less time unengaged from their infants. Protective factors in the development of co-regulation, such as maternal education, are crucial considerations when designing and implementing interventions targeting the parent-child relationship, as well as determining which populations to target with such interventions.

Furthermore, although the trajectory of some patterns of co-regulation were associated with parenting stress and maternal education and moderated the association between parenting stress and child mental health outcomes, more research is needed to establish whether certain interventions, such as emotion coaching and PCIT, would impact co-regulation directly and if so, how this would impact treatment outcomes (i.e., whether and how co-regulation could be a mechanism of change within these interventions).

Conclusion

Taken together, results from Studies 1 and 2 highlight the complex, dynamic nature of mother-infant and mother-child interactions over time. Study 1 began with providing a general overview of the development of co-regulation, showing that both low-and at-risk groups became increasingly synchronous over the first four years of life, but that parenting stress was associated with asynchronous patterns of co-regulation in at-risk dyads. Study 2 explored the implications of these associations for children's mental health, finding that asynchronous forms of co-regulation were risk factors for low-risk dyads, but had a buffering effect for both medically and psycho-socially at-risk groups. Results from these studies contribute to a deeper understanding of how co-regulation develops in adverse circumstances, push against a one-size-fits-all approach to co-regulation, and add to the continuously growing support for the importance of parent-child relationships and their early foundations.

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Appendix A

Sample Informed Consent (Study 1, 6-months of age, full-term and VLBW/preterm groups)

Consent Form
Mother-Infant Interactions

This study is designed to look at infants' responses during social interaction and to study the different types of interaction used by caregivers and their role in social exchange.

I understand that my baby and I will participate in a study lasting approximately 60 minutes. In the first part, my baby will be seated in an infant seat directly facing me. The procedure will consist of several interaction periods, each lasting two to three minutes in length, during which time I will be asked to interact in different ways with my baby. During some periods I will be asked to interact with my baby as I normally do, while in others I will be asked to pose a neutral, still facial expression and remain silent for a brief period. There will be brief breaks separating the interaction periods. In the second part, my baby and I will play together on a carpeted floor for approximately 8 minutes in a designated area, during which time I will be asked to play with my baby as I normally would at home. Under no circumstances will any manipulation be harmful to my baby. Finally, I will be asked to complete several brief questionnaires.

The entire session will be videotaped so that at a later point my baby's responses may be scored. However, these recordings are kept in the strictest confidence and are not shown to others without my permission. I understand that my participation in this study is totally voluntary. I know that I may withdraw at any time and for any reason. I also understand that I may request that the videotape recording of my baby be erased. In the event that the results of the study are published, my name and the name of my baby will be kept confidential. I am also aware that I may be asked to participate again when my baby is 12 and 18 months of age.

In the event that I have any unanswered concerns or complaints about this study, I may express these to Dr. Dale Stack (848-2424, ext. 7565), Dr. Lisa Serbin (848-2424, ext. 2255) or Dr. Alex Schwartzman (848-2424, ext. 2251) of the Psychology Department at Concordia University. In addition, the patient representative of the Jewish General Hospital is Mrs. Laurie Berlin (340-8222, ext. 5833). She can be contacted should I have any questions regarding my rights as a research volunteer.

Thank you for your cooperation.

I, _____, do hereby give my consent for my baby _____ to participate in a study conducted by Dr. Dale Stack at Concordia University, and with the cooperation of the Jewish General Hospital. A copy of this consent form has been given to me.

Parent's signature on behalf of child: _____ Date:_____
Parent's signature: _____ Date:_____
Witness: _____ Date:_____

Appendix B

Sample Informed Consent (Study 1, 6-months of age, psycho-socially at-risk group)

"L'INDIVIDU DANS SON MILIEU: Les parents et leurs enfants"

Directeurs du projet: - Dale M. Stack, Ph.D.
- Lisa A. Serbin. Ph.D.
- Alex E. Schwartzman, Ph.D.

FORMULAIRE DE CONSENTEMENT

Cette étude a pour but d'examiner le développement social des enfants et comment les parents et leurs jeunes enfants jouent ensemble. Je comprends que mon enfant participera à une séance d'observation de 60 minutes divisée en deux parties: Une première partie où mon enfant sera assis(e) dans un siège d'enfant me faisant face. Cette partie sera composée de plusieurs périodes de deux à trois minutes chacune. Durant certaine de ces périodes, je devrai demeurer silencieuse et conserver une expression faciale assez neutre lors de mes interactions avec mon enfant. La seconde partie sera une période de jeu libre où mon enfant et moi jouerons ensemble pour une période de huit minutes environ. A la fin de la séance d'observation, une rémunération totale de $15.00 me sera allouée. Chaque période d'observation sera séparée par une courte pause et les manipulations expérimentales ne sont aucunement dangereuses pour mon enfant. La séance entière sera filmée sur vidéo afin de permettre la cotation des réactions de mon enfant ultérieurement.

Je comprends que ma participation à cette étude est volontaire et que je peux y soustraire mon enfant en tout temps et cela, sans avoir à donner d'autres explications. Je comprends aussi que j'ai le droit d'exiger que le ruban magnétoscopique soit détruit. Je permets que les résultats obtenus soient publiés, sachant que mon nom et celui de mon enfant seront gardés confidentiels. Je comprends aussi que toutes les informations que nous fournissons, qu'elles soient écrites ou filmées, sont strictement confidentielles et qu'elles ne serviront qu'à des fins de recherche. Dans toutes les circonstances, je suis assuré(e) que l'anonymat sera conservé.

Comme le projet "L'individu dans son milieu" est à long terme, je comprends que je pourrais être appelé(e) dans l'avenir pour participer à d'autres étapes de ce projet. Je me réserve le droit de décider, à ce moment, de donner suite ou non à la demande de participation.

Je m'engage volontairement avec mon enfant, _____, à participer à cette étude. Dans l'éventualité où j'aurais des questions ou une plainte à formuler concernant cette étude, je pourrai m'adresser aux directeurs du projet: Dr. Dale Stack (848-7565), Dr. Lisa Serbin (848-2255) ou Dr. Alex Schwartzman (848-2251) du département de psychologie de l'Université Concordia.

Merci de votre coopération.

Signature:_____ Date:_____

Témoin: _____ Date:_____

Appendix C

Sample Informed Consent (Study 1, 12- and 18-months of age, full-term and VLBW/preterm groups)

Consent Form
Mother-Infant Interactions

This study is designed to look at infants' responses during social interaction and to study the different types of interaction used by caregivers and their role in social exchange.

I understand that my baby and I will participate in a study lasting approximately 60 minutes, divided into two main parts. The first part will consist of a period of free play in which my child and I will play together for approximately 15 minutes. The second part will also be a play period, but it will include a series of different activities lasting approximately three minutes for each activity. These observation periods will be separated by short pauses. Under no circumstances will any manipulation be harmful to my baby. Finally, I will be asked to complete several brief questionnaires.

The entire session will be videotaped so that at a later point my baby's responses may be scored. However, these recordings are kept in the strictest of confidence and are not shown to others outside without my permission.

I understand that my participation in this study is totally voluntary. I know that I may withdraw at any time and for any reason. I also understand that I may request that the videotape recording of my baby be erased. In the event that the results of the study are published, my name and the name of my baby will be kept confidential.

In the event that I have any unanswered concerns or complaints about this study, I may express these to Dr. Dale Stack (848-2424, ext.7565), Dr. Lisa Serbin (848-2424, ext.2255) or Dr. Alex Schwartzman (848-2424 ext. 2251) of the Psychology Department at Concordia University. In addition, the patient representative of the Jewish General Hospital is Lianne Brown (340-8222, ext. 5833). She can be contacted should I have any questions regarding my rights as a research volunteer.

Thank you for your cooperation.

I, _____, do hereby give my consent for my baby to participate in a study conducted by Dr. Dale Stack at Concordia University, and with the cooperation of the Jewish General Hospital. A copy of this consent form has been given to me.

Parent's signature on behalf of child: _____Date:
Parent's signature: _____Date:
Witness: _____Date:

Appendix D

Sample Informed Consent (Study 1, 12- and 18-months of age, psycho-socially at-risk group)

"L'INDIVIDU DANS SON MILIEU: Les parents et leurs enfants"

Directeurs du projet:
- Dale M. Stack, Ph.D.
- Lisa A. Serbin. Ph.D.
- Alex E. Schwartzman, Ph.D.

FORMULAIRE DE CONSENTEMENT

Cette étude a pour but d'examiner le développement social des enfants et comment les parents et leurs jeunes enfants jouent ensemble. Je comprends que mon enfant participera à une séance d'observation de 60 minutes divisée en deux parties: Une première partie sera une période de jeu libre où mon enfant et moi jouerons ensemble pour une période de 15 minutes environ. La seconde partie sera également une période jeu, mais sera composée de différentes activités d'environ 3 minutes chacune. A la fin de la séance d'observation, une rémunération totale de $15.00 me sera allouée. Chaque période d'observation sera séparée par une courte pause et les manipulations expérimentales ne sont aucunement dangereuses pour mon enfant. La séance entière sera filmée sur vidéo afin de permettre la cotation des réactions de mon enfant ultérieurement.

Je comprends que ma participation à cette étude est volontaire et que je peux y soustraire mon enfant en tout temps et cela, sans avoir à donner d'autres explications. Je comprends aussi que j'ai le droit d'exiger que le ruban magnétoscopique soit détruit. Je permets que les résultats obtenus soient publiés, sachant que mon nom et celui de mon enfant seront gardés confidentiels. Je comprends aussi que toutes les informations que nous fournissons, qu'elles soient écrites ou filmées, sont strictement confidentielles et qu'elles ne serviront qu'à des fins de recherche. Dans toutes les circonstances, je suis assuré(e) que l'anonymat sera conservé.

Comme le projet "L'individu dans son milieu" est à long terme, je comprends que je pourrais être appelé(e) dans l'avenir pour participer à d'autres étapes de ce projet. Je me réserve le droit de décider, à ce moment, de donner suite ou non à la demande de participation.

Je m'engage volontairement avec mon enfant, _____, à participer à cette étude. Dans l'éventualité où j'aurais des questions ou une plainte à formuler concernant cette étude, je pourrai m'adresser aux directeurs du projet: Dr. Dale Stack (848-7565), Dr. Lisa Serbin (848-2255) ou Dr. Alex Schwartzman (848-2251) du département de psychologie de l'Université Concordia.

Merci de votre coopération.

Signature:_____ Date:_____

Témoin: _____ Date:_____

Appendix E

Sample Informed Consent (Study 1 and 2, 48-months of age, full-term and VLBW/preterm groups)

Consent Form
Mother-Infant Interactions

This study is designed to look at infants' responses during social interaction and to study the different types of interaction used by caregivers and their role in social exchange.

I understand that my baby and I will participate in a study lasting approximately 60 minutes, divided into two main parts. The first part will consist of a period of free play in which my child and I will play together for approximately 15 minutes. The second part will also be a play period, but it will include a series of different activities lasting approximately three minutes for each activity. These observation periods will be separated by short pauses. Under no circumstances will any manipulation be harmful to my baby. Finally, I will be asked to complete several brief questionnaires.

The entire session will be videotaped so that at a later point my baby's responses may be scored. However, these recordings are kept in the strictest of confidence and are not shown to others outside without my permission.

I understand that my participation in this study is totally voluntary. I know that I may withdraw at any time and for any reason. I also understand that I may request that the videotape recording of my baby be erased. In the event that the results of the study are published, my name and the name of my baby will be kept confidential.

In the event that I have any unanswered concerns or complaints about this study, I may express these to Dr. Dale Stack (848-2424, ext.7565), Dr. Lisa Serbin (848-2424, ext.2255) or Dr. Alex Schwartzman (848-2424 ext. 2251) of the Psychology Department at Concordia University. In addition, the patient representative of the Jewish General Hospital is Lianne Brown (340-8222, ext. 5833). She can be contacted should I have any questions regarding my rights as a research volunteer.

Thank you for your cooperation.

I, _____, do hereby give my consent for my baby to participate in a study conducted by Dr. Dale Stack at Concordia University, and with the cooperation of the Jewish General Hospital. A copy of this consent form has been given to me.

Parent's signature on behalf of child: _____Date:
Parent's signature: _____Date:
Witness: _____Date:

Appendix F

Sample Informed Consent (Study 1 and 2, 48-months of age, psycho-socially at-risk group)

"L'INDIVIDU DANS SON MILIEU: Les parents et leurs enfants"

Directeurs du projet: - Dale M. Stack, Ph.D., Lisa A. Serbin. Ph.D. et Alex E. Schwartzman, Ph.D.

FORMULAIRE DE CONSENTEMENT

Cette étude se propose d'analyser les interactions parent-enfant, ainsi que les différents modes d'interactions utilisés et les différentes trajectoires qu'emprunte le développement de l'enfant. En bout de ligne, nous nous attendons à ce que les informations recueillies par cette étude et celles qui vont suivre permettront la mise sur pied de programmes d'intervention préventive.

Je comprends que mon enfant et moi participeront à une session, d'une durée d'environ 2-3 heures, séparée en diverses parties. La première est une période de jeu libre pour mon enfant et moi d'une durée d'environ 15 minutes. La deuxième partie, elle, est aussi une période de jeu, mais avec casse-tête, qui dure environ 10 minutes. Ces deux périodes de jeu seront séparées par une pause. La troisième partie consiste en une évaluation cognitive de mon enfant pendant que je remplirai une série de questionnaires. Les chercheurs sont prêts à faire une deuxième visite, au besoin, pour terminer l'évaluation ou pour parler des résultats. Le processus d'évaluation ne sera en aucun cas néfaste pour mon enfant. A la fin de la séance d'observation, une rémunération totale de $20.00 me sera allouée. Chaque période d'observation sera séparée par une courte pause et les manipulations expérimentales ne sont aucunement dangereuses pour mon enfant. La séance entière sera filmée sur vidéo afin de permettre la cotation des réactions de mon enfant ultérieurement.

Je comprends que ma participation à cette étude est volontaire et que je peux y soustraire mon enfant en tout temps et cela, sans avoir à donner d'autres explications. Je comprends aussi que j'ai le droit d'exiger que le ruban magnétoscopique soit détruit. Je permets que les résultats obtenus soient publiés, sachant que mon nom et celui de mon enfant seront gardés confidentiels. Je comprends aussi que toutes les informations que nous fournissons, qu'elles soient écrites ou filmées, sont strictement confidentielles et qu'elles ne serviront qu'à des fins de recherche. Dans toutes les circonstances, je suis assuré(e) que l'anonymat sera conservé. Cependant, en accord avec la loi sur la protection de la jeunesse, toute information laissant croire à de l'abus physique ou sexuel doit être rapportée à l'Office de la protection de la jeunesse.

Comme le projet "L'individu dans son milieu" est à long terme, je comprends que je pourrais être appelé(e) dans l'avenir pour participer à d'autres étapes de ce projet. Je me réserve le droit de décider, à ce moment, de donner suite ou non à la demande de participation.

Je m'engage volontairement avec mon enfant, _____, à participer à cette étude. Dans l'éventualité où j'aurais des questions ou une plainte à formuler concernant cette étude, je pourrai m'adresser aux directeurs du projet: Dr. Dale Stack (848-7565), Dr. Lisa Serbin (848-2255) ou Dr. Alex Schwartzman (848-2251) du département de psychologie de l'Université Concordia.

Merci de votre coopération.

Signature du parent : _____ date : _____

Témoin : _____ date : _____

Appendix G

Sample Informed Consent (Study 2, 7-years of age, psycho-socially at-risk group)

CHT

« L'INDIVIDU DANS SON MILIEU: Les parents et leurs enfants»
Directeurs du projet: -Dale M. Stack, Ph.D.
-Lisa A. Serbin, Ph.D.

Numéro d'identification: _____

Formulaire de consentement

Je, soussigné(e) autorise les chercheurs du projet «*L'individu dans son milieu*» de l'Université Concordia à rencontrer mon enfant _____à l'école durant la période de classe. Je suis informée que, durant la rencontre à l'école, mon enfant sera évalué au niveau de son fonctionnement intellectuel et académique. J'autorise également les chercheurs à recueillir des informations sur la vie scolaire de mon enfant de la part de son professeur et à obtenir une copie du dernier bulletin de l'année en cours. Finalement, je consens à rencontrer les chercheurs de l'Université Concordia à mon domicile avec mon enfant afin de compléter divers questionnaires sur son comportement et son tempérament. J'accepte aussi d'être filmé(e) avec mon enfant lors d'une session incluant un jeu et des discussions portant sur des résolutions de problèmes.

Je comprends que toutes les informations que nous fournissons, qu'elles soient écrites, verbales, enregistrées ou filmées, sont strictement confidentielles et qu'elles ne serviront qu'à des fins de recherche. Cependant, si après évaluation des examens, mon enfant requérait une attention spéciale, les chercheurs de l'Université Concordia s'engagent à faire le suivi de la rencontre afin de référer les services nécessaires. Dans toutes les circonstances, je suis assuré(e) que l'anonymat sera conservé. Toutefois, selon la loi sur la protection de la jeunesse, toute information indiquant de l'abus physique ou sexuel devra être divulguée à l'Office de la protection de la jeunesse.

Dans l'éventualité où j'aurais des questions concernant cette recherche, je pourrai m'adresser à Luc Bouchard (514-848-2424, ext. 2254, courriel électronique alexes2@vax2.concordia.ca) ou Dr. Dale Stack (514-848-2424, ext. 7565).

Nom:_____ Date:_____
EN LETTRES MOULÉES

Signature: _____

Nom de l'enseignant(e): _____
Année scolaire:_____
Nom du directeur / de la directrice: _____
Nom de l'école: _____
Numéro de téléphone: _____
Adresse: _____
_____

Appendix H

Additional Information on the Analytic Plan (Studies 1 and 2)

To address the Objective 3 of Study 1, which examined how changes over time in co-regulation from 6- to 48-months were associated with parenting stress among full-term, VLBW/preterm, and psycho-socially at-risk dyads, multi-level modelling (MLM) was conducted in *MPlus* (Muthen & Muthen, 2007). In each model, one of the patterns of co-regulation (i.e., symmetrical, asymmetrical, unilateral, unengaged, and disruption) were regressed on one of the scales from the PSI (i.e., parenting distress, parent-child dysfunction, difficult child, and total parenting stress; Abidin, 1995). The variables, child sex and years of maternal education, were also entered as controls for each model. All groups (i.e., full-term, VLBW/preterm, and psycho-socially at-risk dyads) were run together in each model. Altogether, 20 models were run to explore objective 3, which resulted in three statistically significant findings and two trends described in more detail in the Results section of Study 1, Objective 3.

To address the objectives of Study 2, which examined how co-regulation would interact with parenting stress to predict children's mental health outcomes concurrently and longitudinally, moderation analyses were run using the *PROCESS* add-on in SPSS (Hayes, 2013). Within each model, one of three scales from the CBCL (i.e., internalizing problems, externalizing problems, and total problems; Achenbach, 1991) was added as the dependent variable. The independent variable included one of the three sub-scales of the PSI (i.e., parenting distress, parent-child dysfunction, and difficult child; Abidin, 1995), and the moderating variable included one of the five patterns of co-regulation (i.e., symmetrical, asymmetrical, unilateral, unengaged, and disruption). A separate model was run for each scale or pattern of the CBCL, PSI, and co-regulation in each group (i.e., full-term, VLBW/preterm, and psycho-socially at-risk dyads). For Objective 1, which examined the moderating effect of co-regulation in the low-risk full-term group, 45 models were run. For Objective 2, which examined the moderating effect of

co-regulation in both the VLBW/preterm and psycho-socially at-risk groups, 90 models were run. Finally, for Objective 3, which examined the moderating effect of co-regulation at 4-years on children's mental health outcomes at 7-years among the psycho-socially at-risk group, 45 models were run. In total, 180 moderation models were run for Study 2, which resulted in the nine statistically significant findings described in more detail in the Results section of Study 2.

Taken together, the findings from Studies 1 and 2 should be interpreted with some caution and understood in the context of the number of analyses run relative to the number of statistically significant findings, and the increased risk of error. While the results still highlight important considerations for factors associated with mother-child interactions in low- and at-risk groups, as well as potential implications, replication is needed before making definite statements or applying these findings to interventions targeting the mother-child relationship.