A Multi-Method Examination of Mother-Infant Synchrony

as a Predictor of Social and Emotional Problems

by

Shayna Skelley Coburn

A Dissertation in Partial Fulfillment
Of the Requirements for the Degree
Doctor of Philosophy

Approved June 2014 by the
Graduate Supervisory Committee:

Keith Crnic, Chair
Thomas Dishion
David MacKinnon
Linda Luecken

ARIZONA STATE UNIVERSITY

August 2015

ABSTRACT

The parent-child relationship is one of the earliest and most formative experiences for social and emotional development. Synchrony, defined as the rhythmic patterning and quality of mutual affect, engagement, and physiological attunement, has been identified as a critical quality of a healthy mother-infant relationship. Although the salience of the quality of family interaction has been well-established, clinical and developmental research has varied widely in methods for observing and identifying influential aspects of synchrony. In addition, modern dynamic perspectives presume multiple factors converge in a complex system influenced by both nature and nurture, in which individual traits, behavior, and environment are inextricably intertwined within the system of dyadic relational units.

The present study aimed to directly examine and compare synchrony from three distinct approaches: observed microanalytic behavioral sequences, observed global dyadic qualities, and physiological attunement between mothers and infants. The sample consisted of 323 Mexican American mothers and their infants followed from the third trimester of pregnancy through the first year of life. Mothers were interviewed prenatally, observed at a home visit at 12 weeks postpartum, and were finally interviewed for child social-emotional problems at child age 12 months. Specific aspects of synchrony (microanalytical, global, and physiological) were examined separately as well as together to identify comparable and divergent qualities within the construct.

Findings indicated that multiple perspectives on synchrony are best examined together, but as independent qualities to account for varying characteristics captured by divergent systems. Dyadic relationships characterized by higher reciprocity, more time and flexibility in mutual non-negative engagement, and less tendency to enter negative or unengaged states were associated with fewer child social-emotional problems at child age 12 months. Lower infant cortisol was associated with higher levels of externalizing problems, and smaller differences between mother and child cortisol were associated with higher levels of child dysregulation. Results underscore the complex but important nature of synchrony as a salient mechanism underlying the social-emotional growth of children. A mutually engaged, non-negative, and reciprocal environment lays the foundation for the successful social and self-regulatory competence of infants in the first year of life.

ACKNOWLEDGMENTS

It truly takes a village to complete doctoral training, and I am thankful to many people for their guidance, support, and encouragement throughout my graduate experience. Above all, I owe a great deal of gratitude to my mentor and advisor, Keith Crnic, who has had a formative influence on my development as a researcher, teacher, and a person in general. His nonstop encouragement to always pursue ideas from a thoughtful, conceptual foundation has allowed me to gain a depth of knowledge— and ask even more questions than I can answer— in my academic endeavors. Keith has nurtured my intellectual curiosity, willingness to take risks, and creativity, which will no doubt follow me throughout my career. I am grateful to have had the opportunity to work with him closely over the past six years.

I would also like to thank my committee members for their ongoing support and insight in helping me develop my ideas, execute analyses, and interpret my findings. Thanks to Dave MacKinnon for his invaluable help in building my skills and confidence in analytical methodology throughout every milestone in my graduate training. I thank Tom Dishion for introducing me to the theories and methods of dynamic systems and state-space grids, as well as connecting me to his esteemed colleagues, which will no doubt continue to shape my future career. Thank you to Linda Luecken, who has encouraged me and trained me on approaches for using cortisol data to connect behavior with physiology, a goal I have had for the entirety of my graduate training that I have finally begun to attain. In addition to my committee, I would also very much like to thank Ruth Feldman, Tom Hollenstein, and Doug Granger, each of whom volunteered their time to provide training, technical support, and conceptualization for examining global coding of synchrony, state-space grids, and cortisol attunement, respectively.

Another important contribution to my successful completion of this dissertation as well as graduate school is the support I have received from friends and colleagues in the department. It has truly been an honor to combine enthusiasm for clinical research with genuine friendships, which has provided much happiness, stress management, and guidance during this journey. An especially big thank you to the members of the Crnic Parent-Child Relations Lab, who created a warm and intellectually stimulating environment each day. I am grateful for the entire Las Madres Nuevas team of PIs, graduate and undergraduate research assistants, interviewers, and data managers, without whom this dissertation would have not been possible.

Finally, I owe a great deal of gratitude to my husband, Avi, as well as my entire family. Not only did Avi provide me with balance and encouragement during the entire process of graduate school, he exceeded his role as a supportive spouse by also helping me write a program to organize and re-code the rich but complicated data for state-space grids. I thank each of my family members who provided unconditional support and faith in my abilities through each step of this lengthy and complicated training experience.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Table Page

Table Page

LIST OF FIGURES

Figure Page

INTRODUCTION

Interaction synchrony, the "dance" of mutually responsive behaviors in a dyad (Reyna, 2009), is critical to the mother-infant relationship and is highly predictive of infants' later social and emotional functioning (Feldman, 2007a)**.** Synchrony occurs behaviorally as well as physiologically, involving social interaction and co-regulatory systems in a rhythmic exchange between mothers and their infants that begins at birth and continues throughout the lifespan. Specific elements of synchronous behavior in mother-infant dyads evolve as infants learn to reciprocate social behavior and self-regulate, providing a scaffolding for infant development in a supportive environment (Feldman, 2007b). Developmentally appropriate synchrony has been linked to a variety of critical functions in infants, including social-emotional competence, successful self-regulation, and overall health (Harrist & Waugh, 2002). In contrast, constricted, tense, or depressed interactions, typically characterized as "poor" synchrony, has been associated with delayed cognitive and emotional development, poorer psychological functioning, and increased health problems extending into childhood and beyond (Guedeney, Guedeney, Tereno, Dugravier, et al., 2011).

High-risk populations such as families with low socioeconomic status and minority ethnicities are of particular interest in understanding mechanisms related to subsequent problems in early child development. Thus, characterizing the quality of mother-infant synchrony from an early age could provide critical information regarding the subsequent success or risks for a child from such a background. However, much like similar parent-child relationship concepts, the methods for operationalizing and identifying synchrony have been inconsistent in literature. Clarifying conceptualizations as well as improving the measurement and evaluation of essential aspects of synchrony will ensure consistent and effective examination of key mechanisms and their associations to risk and resilience.

The relation between synchrony and developmental outcomes in children is largely unknown among Mexican American families, who are at heightened risk of experiencing adverse child outcomes via stress related to poverty and minority status (Carlson & Harwood, 2003; Halgunseth, 2006). Mexican Americans make up a rapidly increasing proportion of the population, and therefore research concerning children and families within this ethnic group is increasingly important (Lopez, Barrueco, & Miles, 2006). Parenting behaviors, such as high control and demandingness, are often found at higher rates among Mexican Americans (Halgunseth, 2006). Such behaviors are typically negatively associated with synchrony and have been connected to negative child outcomes, although most research that demonstrates such effects involves only Caucasian samples. It is possible that parenting styles may differ depending on cultural orientation, but may not impede successful parent-child relationships or healthy child development (Carlson & Harwood, 2003; Hwa-Froelich, 2004). The present study aims to characterize synchronous interaction as a protective or risk factor for later social-emotional competence between mothers and their infants in a low-income Mexican American sample. In particular, measurement approaches will be compared to assess the interrelations between various methods for observing synchrony and their links to subsequent child social-emotional developmental concerns in a high-risk population.

Mother-Infant Interaction Synchrony

The relationship between a mother and her infant is uniquely vital for healthy development. Even before birth, there is evidence that mothers and infants begin to form meaningful patterns of communication (Bråten, 2009). In the womb, infants experience reciprocity with their mothers through physiological functions and sensations; after birth, contingency and reciprocity appear to be natural features of the mother-infant relationship. Mothers also begin to intuitively interpret expressions from infants and respond to them as if they were deliberate, thus setting the stage to begin utilizing behavior in a truly meaningful way (Feldman, 2007a; Papousek, 2007; Papoušek & Papoušek, 1987). Early mother-infant communication is naturally more heavily dominated by mothers compared to infants, who are simultaneously sensitive to infants' movements, sounds, and facial expressions to interpret the child's internal state (Feldman, 2007a). Often, this sensitivity leads to affect matching, a sign of empathy among caretakers. As infants become aware that there is another person receiving signals, they begin to contribute meaningfully as well (Feldman, 2007a; b).

Although there are many schools of thought regarding the nature of mother-infant communication, the concepts of mutual behavior and rhythmic interaction appear to be common in most theories (Papousek, 2007). The earliest perspective on synchrony was in the context of parenting in mammals, which defined it as the process of continuous exchanges of sensory, physiological, and hormonal input between parent and offspring (Schneirla, 1946; Rosenblatt, 1965). Soon thereafter, this process was adopted for understanding social interactions among humans with respect to nonverbal behaviors such as gaze, affect, and vocalization (Feldman, 2007b). Early communicative sequences between mothers and infants indicated synchronous patterns as indicative of social and emotional attunement within a dyad (e.g., Condon & Sander, 1974; Wolff, 1967; Brazelton, Koslowski, & Main, 1974). *Synchrony,* as currently conceptualized, is the rhythmic process involving behavior, affective states, and biological states between parent and child that together form a single "relational unit" that begins from birth and evolves as infants develop (Feldman, 2007b; Rosenblatt, 1965; Schneirla, 1946).

Due to its early emergence in life as well as its universality, it is believed that synchrony captures one of the earliest and most salient elements of parent-child bonding that occur during infancy, which may be indicative of critical processes including development of social reciprocity, self-regulation, and cognitive stimulation. It begins during episodes in which newborns engage in "alert scanning", during which mothers are most active in communicative behavior. These "alert scanning" periods seem to be specific moments when inborn contingency detection is turned on (Condon, 1974). However, the development and transformation of synchrony over time has only recently begun to be explored, with many questions still unanswered as to the impact of stability and change in synchrony on children's well-being.

Over the developmental period up to the first year of life, synchrony shifts and adapts in phases. In vitro, physiological oscillators drive synchrony, whereas soon after birth, contingency detection is the earliest observable indicator. Between ages 3 to 6 months, synchrony appears in a variety of modalities, including visual, vocal, affective, and touch-related processes. Beginning at nine months, infants begin to acquire intentional interaction skills, including inter-subjectivity and a focus on objects. Finally, at 12 months of age, symbol use and play emerges between parents and their children

(Feldman, 2007a). Clearly, synchrony is a developmental process by which the mother-infant relationship shifts and evolves across the lifespan in conjunction with the infant's socialization to develop lifelong social and emotional skills.

Physiological systems comprise a major element to synchrony. Bonding-related hormones, specific cardiac output, and brain activation occur during synchronous vs. nonsynchronous interactions (e.g., Feldman, 2006; Field, 1984, 1989; Swain, Lorberbaum, Kose, & Strathearn, 2007)**.** For example, mean and peak cortisol levels in mothers and infants have been positively correlated in several samples of mothers and infants (Bright, Granger, & Frick, 2012; Granger et al., 1998; Hibel, Granger, Blair, & Cox, 2009). This indicates a deeply meaningful coordination of both shared behavior as well as shared biology commonly referred to as "physiological attunement" (e.g., van Bakel & Riksen-Walraven, 2008). Disruptions to the quality of the mother-child relationship, as well as other stressors, such as conflict in the family, may moderate cortisol attunement (e.g., Hibel, et al., 2009). The behavioral and physiological signs of synchrony, in conjunction, are likely to provide critical information regarding the mechanisms underlying the strength and resilience of a dyad's relationship.

Synchrony has been associated with a variety of other characteristics of caregiver adaptation to infant signals, including sensitivity, co-regulation, and attunement. At its roots, Ainsworth and colleagues identified ideal maternal behavior to be characterized by sensitive responding to infant communicative signals and states (Ainsworth, Blehar, Waters, & Wall, 1978, p.152), which enables the development of a secure attachment relationship. Similarly, co-regulation originated from the conceptualization of emotion socialization, through which infants learn increasingly responsive behaviors to discrete signals of emotional co-regulation from the parent as an external source of emotion regulation (Eisenberg, Cumberland, & Spinrad, 1998; Evans & Porter, 2009). Attunement, on the other hand, is oriented toward discrete matching of affective states rather than other behaviors or patterns of communication, and is hypothesized to indicate parental empathy and emotional availability (Stern, 1985; Haft & Slade, 1989).

Early concepts related to effective parenting have evolved over time to highlight the importance of more complex, overarching patterns of behavior. For instance, Boom (1997) suggested that a sensitive parent must promote an "interaction flow" that enables fluid social exchange without interruption (Hane, Feldstein, & Dernetz, 2003). Similarly, modern perspectives of co-regulation focus on a system of mutual influencing patterns of "aggregated co-activities" (Fogel, 2000), by which both member of the dyad continuously regulate the behavior of the other in a hierarchy of individual actions and turn-taking (Evans, 2009). As constructs have evolved, the distinction between processes such as mutuality or co-regulation from synchrony becomes more challenging and requires clear operationalization based on specific hypotheses and theoretical models.

Although synchrony is closely associated with many processes, it is distinct in that it specifically targets the rhythm and patterning of dyadic interaction, which is believed to be one of the most critical features of the parent-child relationship in early infancy through adulthood (Feldman, 2007b). One aspect of synchrony is coordination, which involves the timing of behavior in a contingent pattern of interaction, sometimes also referring to matching of affect and other behaviors (Moore & Calkins, 2004). Synchronous or asynchronous behavior and physiological functioning can influence —or be influenced by— maternal sensitivity, affect attunement, and emotion regulation. Early synchrony could be indicative of later functioning on individual and dyadic levels, but does not necessarily target specific behaviors relating to emotions, social engagement, or maternal behavior.

In both behavior and physiology, the key features of synchrony involve the process of interaction rather than face-value content. Synchronicity is inherently a time-sensitive construct because it characterizes the flow, rhythm and repetitions, and overall match of affective states between mother and infant in real time (Beebe, 2000a; Feldman, 2007a). Important temporal features of synchrony include coherence and lead-lag. First, coherence is the degree or synchrony of contingent behaviors in which both members of the dyad change behaviors based on the other. Coherence is related to the fluency and reciprocity of the interaction (Feldman, 2012). Second, lead-lag structure relates to the member of the dyad who is most often driving the interaction. Depending on the developmental state of the infant, mothers may allow their infant to "lead" through sensitive observation and modulation of their behavior to respond appropriately (Feldman, 2012). Another aspect of lead-lag structure is time lag, which characterizes the delay between the change in one partner's behavior and the contingent change in the other's behavior. Previous analyses of synchrony across development have indicated that shifts in lead-lag structure and time lag to synchrony shift between ages 3 and 9 months (Feldman, 2007b). Interactions become more mutual and time lags decrease, reflecting a familiarity with the dyad's interaction style (Feldman, 2007b; Stern, 1985). Finally, the coherence of synchrony is individually stable across the infant's first year. Specific alterations in the temporal parameters of synchrony often indicate pathological conditions within the infant, mother, or context (Feldman, 2007a).

Synchrony and Cultural Differences. Although mother-infant synchrony is genetically driven and present in all cultures, specific interaction processes (e.g., lead-lag structure or time lag) vary across cultures (Carter & Keverne, 2002; Keller, 2000; Leckman, 2004). Mothers from more interpersonal cultures tend to value teaching children to show respect to elders and to be primarily concerned about the needs of others (Halgunseth, 2006). This is often related to highly directive, controlled interactions with their children, which have been connected to higher levels of negativity in toddlers among low-acculturated Mexican Americans (Ispa, 2004). Moreover, parents from Western cultures utilize vocalization, gaze, and object presentation in more coordinated patterns compared to parents from more communalistic societies such as Africa, the Middle East or Far East (Feldman, 2007b). Instead, parents from non-Western societies are more likely to provide more physical contact. Although high overall synchrony may persist, specific features of synchrony (reflected by parenting values) and their effects on children may be affected by culture. Specific details of cultural differences of synchrony and their implications are yet to be explicated (Feldman, 2007b).

Additionally, the risk for postpartum depression is greatly inflated among Mexican American mothers compared to the general population, with an estimate of as much as 35-59% of Hispanic and low-income women reporting PPD (Chaudron et al., 2005). Mothers who struggle with emotional issues, particularly depression, demonstrate decreased maternal sensitivity and emotional expression towards their children (e.g., Feldman, 2007a). Children of depressed mothers are at increased risk for withdrawal and avoidance behavior, low expression of positive affect, and poor synchrony, leading to adjustment problems (Beebe, Jaffe, & Lachmann, 1992; Parke, 2004).

Dynamic Systems Theory

The perpetual changing and updating of actions and responses within interaction synchrony illustrates the complexity of human relationships. The relationship between mothers and their infants, like other dyads, has been studied from a wide range of approaches, many of which have been criticized as overly simplistic to effectively study complex developmental processes (Granic, 2003**.** Dynamic systems (DS) theory offers a perspective which more realistically reflects the constantly shifting, bidirectional process of communication. According to Granic and Hollenstein (2003), *Dynamic Systems Theory* (DS) is a "metatheoretical framework" which involves a "set of equations that specify how a system changes over time", based on abstract theory and applied in different disciplines such as mathematics and physics. The term "DS" refers to the systems themselves rather than the equations, and provides methods for describing how behaviors emerge and stabilize through the system's own feedback processes (Granic, 2003). In this model, communication is viewed as a process that consists of continuous interactive sequences (Beebe, 2000b).

Several principles drive DS theory, and have been informed by models such as general systems theory (Sameroff, 1983; von Bertalanffy, 1968), developmental systems theory (Ford & Lerner, 1992)**,** the ecological framework (Bronfenbrenner, 1989), contextualism (Dixon & Lerner, 1988)**,** transactional perspective (Dumas, 1995), the organizational approach (Cicchetti & Schneider-Rosen, 1986), the holistic-interactionistic view (Bergman L.R., 1997) and the epigenetic view (Gottlieb, 1991)**.** Models associated with DS theory view communication as a bidirectional process involving hierarchically embedded intrapersonal and interpersonal systems. They are built with orientations of equifinality, multifinality, and toward the mechanisms associated with change as well as stability (Granic, 2003). Communication is viewed as a continuous process as an interactive sequence of behavior (Beebe, 2000b). The ongoing pattern over time is viewed as a specific feature of the dyadic relationship. Further, interaction is considered to be bidirectional so that, in the case of a mother and her infant, the mother influences the infant and the infant simultaneously influences the mother. Finally, interactive exchanges are deeply connected to self- and mutual co-regulation processes. Each person is affected by one's own behavior as well as the behavior of the partner (Fogel, 1992; Fogel, 2007). Their behaviors occur through what has been described as a contingency, coordination, or mutual influence, all of which describe this transactional, dyad-dependent process of behavior (Beebe, 2000b; Bråten, 2009).

Key features of the DS framework include attractors, a state space, and multistability (Granic, 2003). Open systems tend to exhibit stable, limited behavioral patterns known as *attractors*, despite the potential for a wide variety of behaviors. Several attractors configure systems into a unique *state space*, which is a model of all possible states a system can attain. In a process known as *multistability*, the state space for living systems includes several coexisting attractors, which are then driven by the dominant attractor at any given moment. Moreover, four key principles are exemplified more strongly in DS than other approaches that are promising for future empirical uses. First, DS theory is primarily focused on the emergence of novel behaviors, as opposed to observation of stability (2003). Second, nonlinear change in developmental systems is considered to be central to its methodological strategies. Third, variability is considered vital data, rather than noise, as an indicator of a less stable system (Thelen, 1991).

Finally, and perhaps most critical, DS approaches are fundamentally oriented toward understanding the unfolding patterns of real-time behavior and their interrelations (Thelen & Smith, 2006). Overall, the complex, nonlinear changes in dyadic behavior and their orientation to time are central to DS theory.

Approaches to Observing Synchrony

Behavioral synchrony in parents and children has historically been examined using systematic observation methods, which apply pre-established coding systems to samples of live or recorded behavior using clearly defined rules (Bakeman, 2005). However, multiple approaches to observation pose a challenge for researchers to determine the most effective method for identifying and quantifying meaningful data. The most common approaches, global and microanalytical ("micro") observation, are similar in that they target specific behaviors of interest and identify such behaviors using scoring systems.

Global and micro coding methods diverge in several important features. Whereas global coding requires inference about concepts existing within an individual or family based on whole samples of behavior, micro coding identifies discrete behaviors moment-to-moment, resulting in a detailed time series of behavior (Bell & Bell, 1989). Micro coding allows for a more complete "snapshot" of interactions between individuals by providing insight into detailed contingencies between individuals, but also may not fully capture the "whole" of important theoretical concepts compared to global methods (Bell & Bell, 1989). From a more practical perspective, micro coding can be tedious when behavioral units are highly complex and longer in duration (Margolin, Oliver, Gordis, O'Hearn, et al., 1998). Although time and funding can be a challenge, utilization of both global and micro analytical measures together are ideal for clarifying theory and more creatively conceptualizing family interaction (Bell & Bell, 1989; Margolin et al., 1998; Repetti, Wang, & Sears, 2012). Nonetheless, ideal methods for objective study of synchrony remains elusive and studies rarely compare methodologies directly (Delaherche, Mahdhaoui, Saint-Georges, Viaux, & Cohen, 2012).

Global Observation. The quality of interaction synchrony can be captured with large-scale observation based on developmentally- and contextually-sensitive clinical perspectives. Historically, complex processes between individuals have been best identified and characterized by observation of specific target behaviors. For example, affective expression within a dyad can be examined to identify attunement of emotional expressivity (Legerstee, Markova & Fisher, 2007). Similarly, the rhythmicity of behavioral exchange between a mother and infant can be detected by observers watching samples of interactions. Global observation is ideally broad and flexible enough to be applied to social interactions at any age, culture, and clinical condition while protecting and preserving theoretical meaningfulness (Feldman, 2012). In particular, observations including children in the first year of life must be established within a developmental framework which considers expected social and cognitive abilities of the child as well as parenting styles which provide a context conducive to the infant's social and emotional growth (Feldman, 2012). Global methods allow for flexibility by informing raters of expected behavior and interactive styles in a substantive approach.

Microanalytic Observation. Dynamic Systems approaches have been valued as a useful conceptual model through which behavior can be interpreted, but have been criticized for their impracticality and over-complexity that precludes data analysis

(Granic, 2006). However, recent advancements in analytical technology and approaches are allowing the principles of DS to be applied as more than simply a theoretical framework. These principles have already been applied in other areas of science as well as developmental, social, and psychopathology research (e.g., Fogel, 1992; Lewis, 1999). Continuous observational data, including physiological and behavioral measures, are appropriate for the sophisticated techniques involved in DS analysis. They are often based on time-series analysis and, when used in a longitudinal method across several waves, can depict change, growth, and temporal patterning using DS methods including state-space grid analysis (Granic, 2003).

State-Space Grid (SSG; Lewis, 1999; see Figure 1) analysis is considered a middle ground of several strategies which combines graphical techniques and simple statistical procedures to capture the descriptive richness of DS concepts while staying true to systems assumptions (Lewis, 1999). SSG analysis, developed by Lewis and colleagues, is a graphical and statistical strategy that allows for identification of individual and group differences. It links the analysis of real- and developmental-time patterns, providing promising options for developmental psychopathologists (Granic, 2006; Granic, 2003). SSGs have been used to represent dyadic behavior, including parent-child interactions and peer relations (Granic, 2003; Granic, Dishion, & Hollenstein, 2006; Lunkenheimer, Albrecht, & Kemp, 2012)**.**

The dyad's behavioral sequence across time is plotted on a grid that represents all possible behavioral combinations (see Figure 1). Like a scatter plot, one dyad member is plotted on the x axis and the other is on the y axis. As a result, each point on the grid represents the overlap of two events, often a simultaneously coded state of the dyad

(Granic, 2003). An example of an SSG trajectory is shown in Figure 2, with a hypothetical pattern of events ranging between combinations of three possible affective states (negative, neutral, and positive) and three engagement states (unengaged, passive, and active) per individual. This technique allows for gathering a variety of theoretically-relevant information, including the ability to examine the number of states (i.e., cells), behavior clusters, track the duration of behavior remaining in certain cells, the speed at which it leaves and returns, and identify the extent to which transitions occur to indicate stability.

Within SSG analyses, dyadic behavior is often evaluated by the duration of time in specific states of interest based on hypotheses regarding meaningful shifts in patterning (Hollenstein, 2011). Matching states typically refer to theoretically relevant behavior states exhibited by both members of the dyad, such as positive affect attunement (Legerstee, Markova & Fisher, 2007). Mismatched states indicate instances in which the dyad has become asynchronous, perhaps because of one individual shifting states and the other not following into an appropriate state. For example, a mother and infant could begin in shared positive affect, but the mother may disengage and become flat and unresponsive to the infant's social bids. Sustained mismatched behavior could indicate low sensitivity (Legerstee, Markova & Fisher, 2007) or lack of emotional repair (Granic, O'Hara, Pepler, & Lewis, 2007). Matched states can also occur in positive or negative domains; dyads often returning to matched negative states have been associated with a more rigid and perseverative relationship, which could relate to poorer functioning overall within the dyad (Weinberg, Olson, Beeghly, & Tronick, 2006). Related, the patterning of interaction could provide unique insight into healthy parent-child relations.

Specifically, flexibility, a broader characterization of affective behavior, has been associated with reduced maternal depressive symptoms and more positive children's adaptive development (Lunkenheimer, Albrecht, & Kemp, 2012). Dispersion is a measure calculated from the grid to summarize the amount of flexibility between various possible states in a dyadic interaction. Each possible temporal characterization of the interaction (e.g., duration, number of transitions, and dispersion within areas of matched or mismatched behaviors) provides useful aspects of the interaction pattern that can be combined to form coherent constructs such as synchrony.

Contextual Considerations

Research has only explored the tip of the iceberg in merging approaches that identify the quality of synchrony in mothers and infants, especially in high-risk populations. Nonetheless, families more likely to face challenging life stressors, such as ethnic minorities living in poverty, are often under-represented in developmental and clinical research. Given the substantial health disparities faced by low-income Mexican Americans, it is particularly important to identify factors which may confer risk or protection against mental health difficulties within this population.

Families with fewer resources often experience reduced access to healthcare and are less likely to seek it out (Briggs-Gowan et al., 2004). It has been estimated that 10-15% of 1- and 2- year old children experience significant social-emotional problems, with higher rates among ethnically diverse urban and suburban children (Briggs-Gowan et al., 2001; Roberts, Attkisson, & Rosenblatt, 1998). Screening in pediatric settings has been recommended by the American Academy of Pediatrics (AAP, 2001) to enhance efforts to identify early social-emotional problems. Although most parents believe that it is appropriate to discuss behavioral/emotional issues with their pediatricians, many do not actually do so when problems exist (Horwitz, 1992; 1998). Shorter office visits under managed care may reduce the likelihood that parents will raise concerns about child behavior (Briggs-Gowan et al., 2004).

In the current population of the United States, Latinos are the fastest growing ethnic group and are disproportionately represented among children living in poverty in the US (US Census Bureau, 2004). Mexican Americans comprise the largest proportion of American Latinos (U.S. Census Bureau, 2003), with that proportion projected to continue to accelerate. Socioeconomic factors, maternal education, and level of enculturation (orientation to Mexican culture), can have a major effect on infant health, child adjustment, problem behaviors, and a variety of other outcomes, especially among ethnic minorities (Lopez et al., 2006). Rapidly increasing birth rates (Knight, 2009) are compounding the need for mental health policy to gain a better understanding of the risks and protective factors associated with the healthy development of children in the low-income Mexican American population. Given the immense number of young children being born into Mexican American families living in poverty, it is critical to attend to the possible factors that could hinder positive development within this high-risk population.

Infant Social-Emotional Development

Parent-child synchrony and other contextual factors likely serve as early risk or protective factors for children’s socio-emotional development. Among the earliest signs of social-emotional (SE) problems is withdrawal, characterized by low or absent levels of facial expression, general activity, vocalization, responsivity, and eye contact (Guedeney, 2001). Although brief withdrawal is normal, more sustained infant withdrawal in the absence of physiological causes (Guedeney, 2001) is associated with attachment problems, autism spectrum disorders, psychotic and pervasive developmental disorders, and infant depression (Milne, 2009; Zero to Three, 1994). In some cases, high mother-infant synchrony is believed to be an important buffer against socio-emotional problems by building the foundation for a child's capacity for intimacy, symbol use, and empathy (e.g., Cohn, 1983; Tronick, 1989). In contrast, low synchrony may serve as an early indicator of developmental problems in infants (Feldman, 2007b). For example, withdrawal is a key feature of an infant's response to a non-contingent relationship, and has often been observed during the non-contingent Still Face experimental task (Cohn, 1983; Cohn & Tronick, 1983; Dickstein, 1998; Field, 1984; Tronick & Weinberg, 1997) as well as in cases of actual maternal depression (Murray, 1997).

Early detection of social emotional problems is critical but also a challenge for clinicians such as pediatricians, who may not necessarily be actively assessing for such concerns. The Brief Infant-Toddler Social and Emotional Assessment (BITSEA, Briggs-Gowan et al., 2004) is a parent-report screening questionnaire for social-emotional/behavioral problems and delays in competence for infants and toddlers. In evaluations of the BITSEA compared to longer questionnaires such as the longer Infant-Toddler Social and Emotional Assessment (ITSEA; Carter, Briggs-Gowan, Jones, & Little, 2003), the BITSEA identified 80% to 95% of infants and toddlers identified by the longer questionnaires as having possible social-emotional and/or behavior problems (Briggs-Gowan et al., 2004). In addition, it appears to detect problems and delays that are relatively enduring over time. A tool such as the BITSEA serves as an invaluable resource for quick assessment of at-risk infants, which improves efforts to identify and intervene with families in need of services. It has been suggested that specific interventions to train parents to read their infants' micro-level signals and respond synchronously may be an effective approach for preventing developmental difficulties and delays in children (Trevarthen & Aitken, 2001; Dollberg, Feldman, Keren & Guedeney, 2006).

The Proposed Study

The first year of life provides unique information pertaining to the dynamic between mothers and their infants as well as first warning signs of potential social-emotional distress. Both physiological and behavioral interaction synchrony are fundamental to the parent-child relationship; accordingly, understanding disruptions to these patterns may be key to identifying maladaptive or unsuccessful dynamics that may lead to distress for both mother and child. Similarly, identifying successful communication between mothers and infants may be equally important for recognizing protective elements of family interaction among high-risk individuals with interdependent social values. New methods for analyzing the complex interaction processes can effectively summarize rich information from live, naturalistic interactions across time. The larger "wholes" of the parent-infant relationship may be integral in characterizing early risk factors like infant withdrawal for signs of interrupted or delayed development. The proposed study examines the methodology for capturing mother-infant synchrony and its putative effects on later infant social emotional competence in a high risk sample of Mexican American mothers and their infants.

There are three primary aims for the proposed study. **The first aim** is to examine methodological approaches to characterize most meaningful and relevant aspects of mother-infant synchrony from three distinct perspectives: global behavioral coding, micro-analytical coding analyzed using State-Space Grids, and matching of stress hormones measured by levels of salivary cortisol between mothers and their infants (Figure 4). **The second aim** is to test the extent to which each of the three approaches to measuring synchrony predict subsequent social-emotional competence in a prospective model based on two time points. **The final and third aim** is to test whether each approach to measuring synchrony uniquely predicts child social-emotional competence above and beyond other constructs, or whether the three methods best form a latent factor for predicting child social-emotional competence (Figure 3).

Hypotheses. It is expected that all three approaches (global, micro, and physiological measurement) will predict social-emotional problems and that they will form a well-fitting latent factor that accounts for more variance than individual approaches. It is predicted that lower levels of synchrony, characterized by less time spent and less frequency of flexible, positive engagement between parent-child dyads, will predict more SE problems. A finding that global, micro-analytical, and physiological approaches cohere into a strong factor would provide support for a multidimensional perspective of the complex parent-child relationship that is measured consistently by all approaches. The larger latent construct of synchrony would support a conceptualization of the mother-infant relationship based on a combination of substantive clinically-relevant behavior, discrete measurable actions over time, and indications of HPA attunement within the dyad. Alternatively, a finding that domains contribute separately to prediction of SE problems would indicate the necessity to evaluate parent-child synchrony from multiple perspectives and with a variety of methodological approaches.

If only certain methods emerge as meaningful, future approaches to synchrony would be informed and specific methodological recommendations could be made for future research.

METHOD

Participants

Participants for the present study are part of the larger Las Madres Nuevas, a longitudinal investigation of 323 Mexican American mothers and their infants. Participant mothers were recruited from Maricopa County, AZ and were eligible to participate if they were pregnant, age 18 or older, fluent in either Spanish or English, self-identified as Mexican American, expecting a singleton delivery, and had a low-income status (eligible for Medicaid or self-reported income below $25,000). Women who consented, but did not deliver a singleton, healthy baby (i.e., the baby did not go home from hospital with mother at discharge) were followed for depression only in the larger parent study, and are not included in the present study sample. Basic demographic characteristics of the sample are presented in Table 1. Mother mean age was 27.80 (*SD* = 6.47), and mean years of education completed was 10.14 (*SD* = 3.20), with an average of two other biological children (*SD* = 1.67). The majority of mothers had a romantic partner (77.4%) and had a household income of less than $15,000/year (73%). Most mothers were born in Mexico (86.4%) and preferred Spanish for their interviews (80.8%), but time in the U.S. ranged widely from 0 to 32 years (*M* = 11.88, *SD* =5.97). Approximately 46% of infants were boys, with mean gestational age 39.3 (*SD* = 1.41) and mean birth weight of 3382.7 grams (*SD* = 487.25).

Procedures

Prospective participants were identified at three Maricopa Integrated Health Systems (MIHS) prenatal care clinics in Maricopa County, which includes Phoenix and a number of surrounding cities in Arizona. In this region, approximately 29% of the population of 3.8 million people is Hispanic. Women were recruited at any point during pregnancy before 34 weeks gestation, and were invited to participate by a female, bilingual interviewer. Informed consent and contact information were obtained at an initial prenatal interview, followed by several home visits and phone calls in the first 6 postpartum months, followed by laboratory visits every six months beginning at 12 months of age. The present study will include prenatal, 12 week and 12 month time points to address developmental interests in the emergence of synchrony beginning at 12 weeks of age, and outcomes at 12 months, with prenatal questionnaire indices serving as control variables. Visits will be referred to in order as T1 (12 weeks) and T2 (12 months). Of 337 mothers who consented and completed a prenatal interview, late in the study, 2 of the 337 became ineligible due to language issues and 1 of the 337 became ineligible due to safety issues in the home. Of the 334 who participated, 10 mothers were excluded from data analysis due to late determination of non-Mexican American status and one was excluded due to her infant receiving a diagnosis of developmental disability. The resulting sample of participants comprises 323 mothers and their infants.

Mother Interviews. In-home interviews were conducted orally in the language of their choice of Spanish (80.8%) or English (19.2%), with interviewers recording participant responses on laptops. Women were provided visual response cards using written and graphic cues to illustrate item response formats. Mothers were compensated monetarily and with small gifts (e.g., body lotion, baby rattle): $75 each for their participation in the prenatal interview, $40 for T1 and $100 for T2. To reduce burden, planned missingness was incorporated into the design, such that participants completed three of four visits in the first six months postpartum based on previously selected randomized assignment. Each visit was scheduled to last approximately 1.5 hours. Additional data was collected via phone interview for mothers to answer questions regarding their child's social-emotional functioning at 12 months of age.

At the time of this analysis, all participants (n=323) completed the prenatal interview and a subsample completed the visit at T1 (n=205), and T2 via phone interview (n=188). Note that, due to a planned missingness strategy, all families completed T1 but some families completed T2. At the beginning of 12 month laboratory visits, an additional 30 of the 323 participants were unable to be reached, 3 requested to stop participation, and 5 requested to stop all involvement with the study. Although approximately ten additional families are anticipated to complete T2, 188 to date have completed T2 questionnaires.

Mother-Infant Interaction Tasks. A series of mother-child interaction tasks were conducted at each postnatal home visit (T1), which were recorded with two video cameras. During home visits, five tasks were completed: free play, arm restraint, soothing, teaching, and peek-a-boo. Salivary cortisol samples (P1-P4) were collected from mothers and infants prior to beginning and following completion of all tasks. The first sample of cortisol was collected between 8:30 AM and 5 PM (median time = 12:00 PM). The teaching task was selected for inclusion in the proposed investigation because it provides the best opportunities to observe mother-infant communication patterns and changes in expression. During the teaching task, mothers were given toys with instructions to "teach" the baby to complete a specified task, being told it was a "game of abilities". Tasks were selected to be one to two months beyond the expected abilities of the infant and increased in difficulty at each visit. At the 12 week visit, mothers were asked to show their child how to lift an overturned cup, revealing a cube inside. This task was designed to produce mild frustration.

Measures

Demographics. Participants reported information about themselves and their families in a number of domains that may be relevant as contextual variables for examining mechanisms of the mother-infant relationship and subsequent development. Specifically, information was collected on country of birth, mother's age at intake, marital status, estimated annual household income, years of education completed, and number of other children. Demographics were included in all analyses as possible covariates and were removed if found non-influential.

Mother-Infant Synchrony. Observational data provides important information from impartial judges regarding the dyad's behavior. Global and micro-analytical and global behavior rating systems, as well as physiological measurement of cortisol, were utilized to capture synchrony from multiple methodological perspectives. These data identify a wealth of detailed behavior changes across several domains in mother-infant interaction and communication.

Global Behavioral Synchrony. The Coding Interactive Behavior (CIB) Manual (Feldman, 1998) is a global rating system for adult-child interactions that includes specific a code for withdrawal and social avoidance. Each code is rated on a scale of 1 (a little) to 5 (a lot) that can be aggregated into composites to identify degree of synchrony within each dyad using subscales “Reciprocity”, “Fluency”, and “Child-Led”. High reciprocity is defined as mutual turn-taking between mother and infant. Related, high levels of fluency are considered to be consistency of the rhythm of behavior across the interaction. Finally, high child-led behavior is characterized by the interaction focusing mainly on the child’s interests and needs rather than those of the parent. Together, these three aspects of dyadic behavior are believed to capture synchrony in its mutual attunement, rhythmic, and sensitive nature of the relationship. The CIB has been validated with strong internal and external validity (r =.75), including convergence with clinic referred social-emotional disorders such as depression and autism spectrum disorders (Feldman, 2012).

The CIB was completed by trained undergraduate coders, and training and reliability were completed to the standards described above for behavioral coding. Coders are trained according to CIB procedures, including 85% agreement within a 1-point window. Coders reached an average of 90% agreement upon completion of training and retained an average 95% agreement with ongoing data collection. In addition, twenty percent of all videos were checked against master coders to maintain adequate reliability and reduce coding drift.

Micro-Analytic Behavioral Synchrony. The Infant and Maternal Regulatory Scoring Systems (IRSS and MRSS, respectively; (Tronick & Weinberg, 1990) were adapted for use in this study. The IRSS and MRSS are systems for micro-coding behaviors that represent communication and expression of internal states and desires within one member of a dyad. All mother and infant behaviors were coded independently of the other partner's behavior by a separate coder. Behaviors that were coded for both mothers and infants were affect (possible codes: positive, neutral, negative) and engagement (possible codes: passive, neutral, active) with additional behaviors coded based on appropriate developmental concerns (self-comfort/mother comfort). Mother and infant behaviors and expressions were coded by trained undergraduate research assistants in real time using Noldus 9.0 software. Each coder rated specific behavior within one or two categories. Graduate student master coders were trained to appropriate criteria (kappa >.70; ICC >.80), and reliability checks for a minimum of 20% of the each coders' work as well as 15% of all videos will be carried out across the duration of the project to minimize drift over time. Micro-coding is the most time-consuming task but provides rich information regarding the complexity of time patterning in mother-infant synchrony.

Synchrony within a micro-analytical system was operationalized as a combination of tendency to spend more time and return more quickly to a mutually non-negative, engaged state (NNE). First, "flexibility" of the interaction was operationalized as dispersion across cells. Dispersion is computed by an algorithm incorporating the number of different cells visited (Lamey et al., 2004). Greater flexibility, indicated by higher dispersion, is indicative of more distinct cells visited. Finally, temporal aspects within the content-specific region NNE were operationalized by duration per cell and return time, from which attractors and repellers within a system can be indicated (Granic & Lamey, 2002).

An important aspect for micro-analytical observation is grid-wide patterning of behavior. Overall grid flexibility, measured by dispersion, accounts for a general tendency to enter a variety of states regardless of content of the interaction. In addition, “predictability” of the interaction was operationalized using entropy, an indicator of chaos in a system related to the likelihood that transitions from cell to cell are predictable. Higher levels of predictability are indicated by lower entropy, whereas low predictability is indicated by lower entropy and could be considered more chaotic. Entropy was calculated on the basis of duration as well as number of visits to each cell.

Physiological Synchrony. Biological measures were included as a component in measurement of mother-infant interaction to provide additional data on synchrony beyond observable behavior. Salivary cortisol was obtained from mothers and infants immediately prior to beginning the first task (P1) as well as zero (P2), 20 (P3), and 40 minutes (P4) following completion of all tasks. Samples were collected using the Salivette and Sorbette sampling devices (Sarstedt, Rommelsdorf, Germany; Salimetrics Inc, State College, PA). Mothers were asked not to feed the baby for 30 minutes prior to collection. Saliva samples were packed in dry ice and mailed to Salimetrics Inc where they were assayed for free cortisol. To correct for deviations from normality, cortisol values were log-transformed.

Control Variables. Proper analysis of biological measures requires careful consideration of demographic and physiological factors that may confound or account for variance. Cortisol levels and reactivity can be influenced by a variety of variables that are likely unrelated to the prenatal IVs, including time of infant waking or most recent feeding, sampling time of day, breastfeeding status; and mother’s use of prescribed or OTC medications, caffeine, or tobacco, as well as age, body mass index, menstrual cycle, hormonal contraceptives, recent meals, exercise, and physical illness. These variables were considered as potential covariates.

Infant Social Emotional Problems. To assess infant socio-emotional problems at the 12 month laboratory visit, a mother-report questionnaire was completed. At 12 months of age, mothers were called on the telephone to provide answers orally to the Brief Infant-Toddler Social and Emotional Assessment (BITSEA; Briggs-Gowan et al., 2004). The BITSEA is a well validated screener for social withdrawal and delays in competence for infants and toddlers. The BITSEA has been found to identify 80 to 100 percent of children later identified as having possible SE and/or behavior problems across various settings (Briggs-Gowan et al., 2008, 2004, 2001).

Analytic Strategy

Initial data analyses were conducted to summarize and characterize the data using SPSS 13.0 (SPSS Inc, Chicago, IL), and hypotheses were subsequently tested using Mplus 6.12 (Muthén & Muthén, 2007). Because this study incorporated a planned missingness strategy into its data collection methodology, full information maximum likelihood (FIML) estimation was utilized for all analysis, which allows for multiple imputation of missing data and is a less biased procedure for data that is missing at random than listwise or pairwise deletion (Enders, 2001). Analysis of outliers examined and explored the influence of any possible errors in all variables. Potential confounding variables such as age, household income, or number of biological children, were examined as relevant covariates for subsequent analyses. Given the longitudinal design and sample demographics, attrition was low and and not impactful on sample characteristics (Little & Rubin, 1987). For each domain (global, micro, and physiological), the latent factor as well as manifest variables were used for separate subsequent path analyses in Aims 2 and 3. Final models were retained based on fit within each individual domain and its associations with dependent variables.

Analyses for Aim 1. The purpose of aim 1 was to examine three distinct methods of observing synchrony in mother-infant dyads in order to better characterize meaningful aspects of synchrony. It was predicted that each hypothesized factor or measure of synchrony would be supported in measurement models for a latent factor within domain (global, micro, or physiological; Figure 4). Preliminary analyses examined distribution of data, normality, and inter-correlations for each variable of interest to form theoretically-based manifest and latent variables.

First, globally coded mother-infant behaviors measured by the CIB (reciprocity, adaptation-regulation, fluency, and child-led behavior) were examined for overall distribution of scores and the inter-correlations among the behaviors. CIB behaviors were then combined to test a measurement model for a latent global synchrony factor at T1. Second, state-space grid (SSG) analyses (Lewis, 1999) were completed using GridWare (Hollenstein, 2011) to compile and characterize synchrony using microanalytic behavioral data. Finally, synchrony from a physiological attunement perspective was examined based on salivary cortisol in mothers and their infants.

Cortisol attunement has been examined with a variety of approaches that tap into individual approaches to measuring dyadic relations of cortisol between mother and child. First, the samples were cleaned for outliers and inappropriate values, as well as flagged for several potentially influential variables, such as medications, pregnancy, and recently eating or drinking. As there is not an established "gold standard", two methods were attempted and compared to identify the most accurate manner in which to characterize salivary attunement between mothers and their infants.

The first approach was to create a latent "trait cortisol" factor using each of the four samples for mothers and their infants. This involved using all four samples (P1-P4) from mother and infant together to create a single factor for cortisol attunement. Follow-up analyses examined manifest forms of cortisol, which used an absolute difference score between area under the curve with respect to ground (AUCg; Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003) between mother and infant across the entire visit. AUCg scores were log-tranformed (base 10) prior to computing a difference score. Very little is known regarding the nature of salivary cortisol, as well as attunement with mother, at this age of twelve weeks postpartum. Therefore, this method was exploratory in nature and was examined to better explicate the physiological HPA functioning of infants in relation to their mothers across the interaction.

Analyses for Aim 2. The purpose of the second aim was to evaluate the relation between mother-infant synchrony and infant SE problems. First, the dependent variable, Social Emotional problems at T2, was examined using structural equation modeling to test a latent factor consisting of dysregulation, internalizing, and externalizing symptom subscales (which consist of all mutually exclusive items) from the BITSEA (Briggs-Gowan et al., 2004). Subsequently, each domain of synchrony (global, microanalytic, and cortisol) was tested as a predictor individually in a regression model predicting SE problems to examine individual effects. SE problems were characterized first using a single latent factor and then followed up with models examining association with the individual domains of BITSEA (externalizing, internalizing, and dysregulation). Final models were retained for each construct of synchrony (micro, global, and cortisol) based on fit within a latent factor, when applicable, or manifest variables, based on overall fit of the model. Next, the three measures of synchrony were included in individual path models of T2 social-emotional problems regressed on synchrony at T1. Covariates from prenatal interviews such as mothers' marital status, age, education, and household income were included to account for possible differences relating to alternative variables.

Analyses for Aim 3. The third aim examined the unique effects of all synchrony constructs combined on child SE problems as well as whether the three constructs of synchrony (global, microanalytic, or cortisol) converged as a single latent factor for synchrony. For each domain (microanalytic, global, and cortisol), synchrony variables at T1 acquired from Aim 1 were included together as simultaneous predictors of social-emotional problems in children at T2. The final regression model was a multivariate prospective SEM including all three domains of synchrony (T1) predicting to SE problems (T2) (Figure 5). Significant paths indicate continued influence of the parent-infant relationship on subsequent child outcomes. They also highlight the salience of synchrony at early ages as indicators of future child development.

Next, indicators for global, microanalytic, and cortisol synchrony constructs were all tested in a measurement model as manifest indicators on a single latent variable, "Synchrony". It was expected that the following variables would be included: (1) global measures: global reciprocity, global fluency, and global child-led behavior; (2) micro measures: micro nonnegative engagement dispersion, micro nonnegative engagement return time, and nonnegative engagement duration per cell, as well as grid-wide dispersion and visit entropy; and finally, (3) cortisol for mother and infant at all samples of T1. Based on the combination of variables with sufficient fit, the resulting latent factor was tested as a predictor of social-emotional problems at T2 (Figure 6).

RESULTS

Descriptive Statistics

Descriptive statistics for all study variables are shown in Tables 1, 2, and 3. According to recommended limits of skew (<2) and kurtosis (<7) by West, Finch, & Curran (1995), variables which exceed these limits present difficulties for maximum likelihood estimation used in structural equation modeling (SEM). Nonnormality can inflate the overall model fit chi square value can result in underestimation of standard errors of path coefficients and consequently over-estimate significance. Most variables were normally distributed; however, the Internalizing Problems subscale of the BITSEA exhibited skew and kurtosis (2.23 and 9.18, respectively), reflecting a narrowed range from low endorsement of internalizing problems. Examination of the frequency table for Internalizing Problems indicated that the median and mode scores were both low (2 and 2, respectively), with the range of endorsed ratings from zero (n=42, 13%) to eleven (n=1, .3%) problems. Eighty percent of participants endorsed two or fewer internalizing problems on the BITSEA. This variable was transformed by taking the square root of each score to correct for this non-normality (internalizing skew = 2.23, after transformation skew = -.23). Regression diagnostics were performed in order to assess for multicolinearity, outliers, and influential data points on each model. No cases were identified as influential within models estimated.

Global Synchrony. Global measures of dyadic interaction were examined based on four key characteristics from the CIB system: reciprocity, adaptation-regulation, fluency, and child-led behavior. These four aspects of dyadic behavior are presumed to promote a rhythmic, fluid, synchronous interaction. All CIB variables examined were relatively normally distributed and required no additional transformation or cleaning. Each dyadic measure was distributed across the full possible range (1 to 5) based on the CIB scoring system.

Micro Synchrony: State-Space Grids (SSG). Within the perspective of micro-analytical behavior analysis, a combination of overall characteristics as well as region-specific variables were examined. Using behavioral micro-coded observation, the dyad's behavioral sequence was plotted on a SSG (Granic & Hollenstein, 2003). Final grids (full sample aggregated in Figure 7) characterize the durations of shared or degree of engagement and affect for each dyad to create temporal scores (mean duration per cell, mean return time, and dispersion) for regions of interest (region of all nonnegative engaged behavior as well as region of positive engaged behavior, "NNE"; see Figure 2) at T1. Grid-wide flexibility (measured by dispersion) and predictability (measured by entropy), as well as region-specific NNE duration per cell, NNE return time, and NNE dispersion, were identified as theoretically relevant variables of interest.

Overall dispersion for the entire grid was varied, ranging from .05 (very rigid) to .90 (very flexible), but tended to be moderately flexible during this structured interaction prompted by a teaching task (M = .60, SD = .18). Overall predictability (entropy) is also summarized in Table 2; no dyads reached absolute zero entropy, which would represent a state of absolute predictability (M = 1.75, SD = .39 for visit entropy). Predictability varied considerably within the dyads, ranging from .67 (more predictable) to 2.51 (more chaotic). Contrasting exemplar dyads are represented in Figure 8 (A and

B). The dyad on the left (Dyad A) was characterized by dispersion of .41 and visit entropy of 1.59. In contrast, the dyad on the right (Dyad B) was characterized by dispersion of .86 and visit entropy of 2.41. These scores capture the more rigid and predictable quality of Dyad A, in contrast to the more flexible and chaotic Dyad B. Clearly, variation was observed among dyads regarding flexibility and predictability throughout the full state space grid.

Regarding NNE region of interest, mother-infant dyads spent the majority of their time in NNE states (*M* = 163.33 seconds, or 54.4%, *SD* = 107.72) compared to other states involving at least one member entering unengaged or negative states. Dispersion was calculated for dyads entering more than one cell within the NNE region (93.5%) with moderate dispersion (*M* = .48, *SD* = .23). Although no dyads reached dispersion of 1.0 (visiting all possible states within the grid) for any region, variability was high, with maximum dispersion reached in NNE at .90.

Physiological Attunement. Cortisol output within each home visit (four samples per visit) were cleaned for outliers that may have occurred due to problems with detecting cortisol (also indicated by physiologically impossible salivary levels of μg/dl >4) and examined for additional influential cases. Next, each sample was subject to natural log transformation to correct for deviations from normality according to recommendations by Tabachnick & Fidell, (2001) (mother *M* skew = 1.81; after transformation mother *M* skew = -.25; infant *M* skew = 3.70; after transformation infant *M* skew = .40). Additional covariates (Table 2) were examined which could be relevant to possible alternative explanations for cortisol levels, including sampling time of day, time of infant waking or most recent feeding, breastfeeding status; and mother's use of prescribed or OTC medications, caffeine, or tobacco, as well as age, body mass index, menstrual cycle, hormonal contraceptives, recent meals, exercise, and physical illness. Correlations with P1-P4 cortisol samples (Table 4) indicated that time of day of the baseline sample was influential on mother cortisol at P1-P4 (P1 r = -.56, $p < .01$; P2 r = -.54, $p < .01$; P 3 r = -.53, $p < .01$; P 4 r = -.52, $p < .01$) as well as infant cortisol at P1- P3 (P 1 r = -.25, $p < .01$; P2 r = -.22, $p < .01$; P3 r = -.17, $p < .05$), with later times associated with lower levels of cortisol. No other covariates were identified as influential to cortisol for mother or infant at any sampling time point.

Correlations. Correlations among key study variables are shown in Table 5. All CIB dyadic measures of synchrony (Reciprocity, Adaptation-Regulation, Fluency, and Child-Led) were positively inter-correlated. In relation to SSG micro variables, greater levels of all CIB dyadic measures were associated with greater levels of flexibility (dispersion in both NNE and the whole grid), less overall predictability (grid entropy), and shorter NNE return time. No CIB measures were related to the mean duration in nonnegative engaged states. More reciprocity and fluency was associated with lower infant cortisol at T2 and all four CIB measures were associated with lower infant cortisol at T3. However, CIB was not associated with any SE problems (externalizing, internalizing, nor dysregulation) at T2.

Among micro-measures of SSG characteristics, greater NNE flexibility (dispersion) was associated with shorter NNE duration per cell and shorter NNE return time, but greater overall flexibility (grid dispersion) and less predictability (higher visit entropy). Longer NNE duration per cell was associated with shorter NNE return time, less grid dispersion, and more predictability. More overall flexibility (grid dispersion) was associated with less predictability (higher visit entropy). Thus, dyads with higher nonnegative engaged flexibility tended to be less flexible and less chaotic across the larger grid, lingered less in individual cells, and returned more quickly to the region when behavior became unengaged or negative. In relation to cortisol measures, greater levels of overall flexibility were associated with higher levels of mother T1 cortisol. In addition, greater levels of NNE flexibility were associated with lower infant cortisol at T3, whereas lower predictability (higher visit entropy) was associated with greater infant cortisol at T1. In relation to child SE problems at T2, greater overall flexibility and lower predictability was associated with more internalizing problems.

Turning to cortisol measures of mothers and infants, mother cortisol was positively inter-correlated and infant cortisol was positively inter-correlated, but mother cortisol was not consistently related to infant measures of cortisol. However, mother and infant cortisol were positively related within each time point; that is, T1 mother cortisol was positively associated with T1 infant cortisol, as well as pairs of cortisol at T2 and T3, respectively. Nonetheless, mother and infant cortisol at T4 were not significantly related. No measures of cortisol were associated with child SE problems at 12 months postpartum.

Results for Aim 1: Latent and Manifest Synchrony Variables

To test whether multiple aspects of hypothesized dyadic synchrony were related to a larger construct of synchrony, latent variables were created within subsequent models. Overall, several latent factors for individual approaches to measuring synchrony did not consistently reach adequate fit, even after adjustment based on modification indices and theoretical conceptualization. Manifest variables were subsequently maintained for additional testing for Aim 2.

Global synchrony (CIB) was first estimated including reciprocity, fluency, and child-led interaction. Model fit measured by CFI and TLI were slightly below adequate fit, and therefore the best-fitting aspects of CIB were retained in the subsequent model (reciprocity, fluency, and child-led interaction; Table 6). The model was just-identified so chi-square was zero and fit was perfect (χ^2 (0, N=169) = 0, p < .001; RMSEA = 0.00; CFI = 1.00; SRMR = 0.00). Reciprocity, fluency, and lead-lag significantly loaded onto a single latent factor.

Next, micro synchrony (SSG) was estimated which included NNE flexibility (dispersion), NNE mean duration (per cell), and overall flexibility and entropy. The initial model did not meet criteria for adequate fit (χ^2 (5, N=154) = 64.11, p < .001; RMSEA = .28; CFI = .75; SRMR = .15). A follow-up analysis tested the SSG factor removing NNE return time, which did not fit onto the factor in the original model. The resulting model (Table 7) was adequate in fit on some indices (χ^2 (2, N = 154) = 14.56, p < .001; RMSEA = .20; CFI = .93; SRMR = .045). However, RMSEA was too high to reach criteria for adequate fit, suggesting that factor loadings may be misspecified (Hu & Bentler, 1999). Follow-up models based on modification indices did not improve model fit.

Finally, physiological attunement was examined as a latent factor. Cortisol samples across P1 through P4 were then specified to load onto a latent "trait" factor for mother and baby separately. Next, a dyadic latent "trait" factor consisting of all samples for mother and baby together was subsequently tested (D. Granger, personal communication, April 4, 2014; Shirtcliff, Granger, Booth, & Johnson, 2005). Mother and infant data fit on separate factors of mother cortisol and infant cortisol with a path between the two factors (Table 8) but was somewhat below criteria for adequate fit (χ^2 (19, N = 185) = 172.11, p < .001; RMSEA = .21; CFI = .88; SRMR = .08). Nonetheless, each measure of cortisol within baby samples and within mother samples loaded well onto their respective factors. However, mother and infant data did not load fully in a single “dyad trait” factor for cortisol. Therefore, individual factors were retained for mother and infant “trait” cortisol. The measures of synchrony within different domains were used in predictive models as manifest variables. Due to theoretical importance and the possibility that fit would improve once additional variance was accounted for in subsequent path models, each latent factor was tested in addition to other alternative approaches to quantifying cortisol attunement for Aim 2 and Aim 3.

Results for Aim 2: Path Models for Synchrony with Child SE Problems

In preparation for path models examining prospective relations to child SE problems at one year of age (T2), a measurement model for child SE problems at T2 was examined with externalizing, internalizing, and dysregulation problems as manifest variables (Table 9). The measurement model was just identified (χ^2 (0, N = 188) = 0, p = 0, RMSEA = 0; CFI = 1.00; SRMR = 0). All three BITSEA subscales loaded onto the latent factor.

Next, individual path models were estimated between global (CIB), micro (SSG), and physiological (cortisol) measures of synchrony at T1 and subsequent SE problems at T2. Overall, individual path models for CIB, SSG, and cortisol measures did not individually predict the BITSEA latent factor, before nor after accounting for covariates.

Moreover, fit was not adequate for most models. For global CIB synchrony (Table 10), fit was good (χ^2 (20, *N* = 323) = 18.54, *p*=.60; RMSEA = .00; CFI = 1.00; SRMR = .04) but CIB did not relate to BITSEA (*B* = .07, p=.62). The model between micro SSG synchrony and BITSEA did not reach all criteria for adequate fit (χ^2 (28, *N* = 323) = 60.56, $p < .001$; RMSEA = .06; CFI = .88; SRMR = .07). Micro SSG as a latent measure was not associated with SE problems measured by a latent BITSEA factor. Finally, a model for cortisol and BITSEA (Table 12) was estimated, including a path of mother cortisol regressed on infant cortisol to test presumed influence from dyadic attunement. This model between cortisol and BITSEA did not fit the data well (χ^2 (68, *N* = 323) = 220.90, $p < .001$; RMSEA = .08; CFI = .88; SRMR = .06). Mother and infant cortisol were positively associated (*B*= .27, $p < .001$), consistent with hypothesized attunement between mothers and infants. Moreover, higher infant cortisol was associated with fewer SE problems measured by the latent BITSEA factor (*B* = -.28, $p < .05$). Thus, only infant cortisol was associated with SE problems using individual latent path models.

Follow-up analyses examined manifest variable models for each domain of synchrony without latent factors, due to inadequate fit for several measurement models. All manifest variables for each hypothesized synchrony construct, as well as for 12 month child SE problems from the BITSEA, were tested in separate path models within domain. First, for the model examining global CIB variables (Table 13), reciprocity, fluency, and child-led behavior did not predict subsequent child externalizing, internalizing, or dysregulation problems. However, mother prenatal depression was associated with elevated internalizing (*B* = .23, $p < .01$) and dysregulation (*B* = .19, $p < .01$) problems.

For the model examining micro SSG variables (Table 14), return time was re-introduced into the model due to its hypothesized importance in the observation of synchrony. Higher levels of NNE flexibility was associated with fewer externalizing problems (B = -.26, SE = .13, $p < .05$). Longer durations spent in cells of NNE were associated with lower levels of internalizing problems (B = -.34, SE = .15, $p < .05$). In addition, higher levels of overall flexibility was associated with higher levels of internalizing problems (B = .32, SE = .15, $p < .05$), and marginally associated with higher levels of dysregulation problems (B = .32, SE = .17, p =.06). Finally, more predictability of behavior (low visit entropy) was marginally associated with reduced externalizing (B = -.27, SE = .15, p=.08) and internalizing (B = -.27, SE = .16, p = .08) problems, and longer time to return to the NNE state was marginally associated with internalizing problems (B = -.27, SE = .14, p=.06).

The final model examining separate domains of synchrony utilized several approaches to identify the best method for characterizing mother-infant physiological attunement. First, existing latent factors for mother and infant cortisol were examined with manifest variables for child SE problems from the BITSEA (externalizing, internalizing, and dysregulation) (Table 15). Findings for all path models were unaffected by including time of day as a covariate, and were dropped to maximize model fit when possible. Fit was somewhat below cutoffs for adequate fit (χ^2 (58, N = 323) = 214.04, $p < .001$; RMSEA = .09; CFI = .88; SRMR = .06). Although infant cortisol was associated with a latent measure of SE problems, the model using manifest variables for internalizing, externalizing, and dysregulation problems separately indicated only a marginal association. Higher infant cortisol was marginally associated with fewer dysregulation problems (*B* = -.21, SE = .11, *p* =.07). Higher levels of mother prenatal depressive symptoms was also associated with increased internalizing (*B* = .23, SE = .07, *p* < .001) and dysregulation (*B* = .23, SE = .07, *p* < .001) problems.

Next, a difference score was computed for cortisol after aggregating samples from all four time points with the 12 week visit (P1-P4) to calculate an area-under-the curve with respect to ground (AUCg; Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003) for each dyad. AUCg for both mother and infant cortisol were skewed and kurtotic and were log-transformed (base 10) to correct for deviations from normality (Nicolson, 2008; mother skew = 9.45, after transformation skew = .36; infant skew = 1.97, after transformation skew = .27). A difference score for the absolute value of AUCg mother minus AUCg infant was computed and incorporated into a path model to examine associations to SE problems (Table 16). Greater differences between mother-infant AUCgs were associated with fewer dysregulation problems (*B* = -.26, SE = .12, *p* < .05).

Results for Aim 3: Multivariate Path Models with Child SE Problems.

The final aim was to examine the unique versus shared effects of synchrony across all domains in relation to child SE problems at 12 months postpartum. Combined multivariate path models were estimated for the two approaches of measuring cortisol (trait cortisol and attunement measured by AUCg). Then a latent model was tested to explore the nature of global, micro-analytical, and physiological measurements as potential aspects of synchrony that may operate together in relation to risk for SE problems.

Combined Path Model 1 (Latent trait cortisol). When combined into a full path model including all three latent constructs of synchrony within a model for all measures predicting each aspect of child SE problems, the model did not converge due to exceeding iterations. Therefore, a follow-up manifest variable model was examined rather than a latent model (Table 17; Figure 9); the one exception was cortisol, which was maintained as separate mother and infant latent factors due to the necessity to appropriately address overall cortisol rather than values individually. Fit was adequate for most measures (χ^2 (114, N = 323) = 269.59, $p < .001$; RMSEA = .07 CFI = .89; SRMR = .05). Mother and infant cortisol were positively associated with one another (B = .27, SE = .08, $p < .01$) consistent with previous hypotheses and analytical models of mother-infant attunement.

Several associations were observed for this model utilizing manifest measures of global synchrony, micro synchrony, and child SE problems. Aspects of synchrony including reciprocity, flexibility, duration in NNE, and infant cortisol were associated with SE problems within at least one domain. Regarding associations with child externalizing problems at 12 months of age, higher levels of infant trait cortisol were associated with lower levels of externalizing problems (B = -.24, SE = .11, $p < .05$). In addition, lower levels of nonnegative engaged flexibility (NNE flexibility; B = -.27, SE = .13, $p < .05$) and higher levels of predictability (grid visit entropy; B = .31, SE = .15, $p < .05$) were associated with higher levels of externalizing problems. No measures of global synchrony were related to externalizing problems.

Two measures of synchrony, both from microanalytical observation, were related to internalizing problems. Shorter durations in nonnegative engagement (NNE duration per cell) were associated with higher internalizing problems (B = -.34, SE = .14, $p < .05$). In addition, more flexibility across all states of affective engagement (grid dispersion) was associated with higher levels of internalizing problems (*B* = .33, SE = .16, $p < .05$). No global or physiological measures of synchrony were associated with internalizing problems.

Finally, several synchrony indices were associated with risk for dysregulation problems. Lower levels of CIB reciprocity (*B* = -.49, SE = .22, $p < .05$), higher levels of overall flexibility (*B*=.39, SE = .09, $p < .05$), and lower levels of flexible nonnegative engagement (NNE dispersion) were associated with higher levels of dysregulation problems (*B* = -.31, SE = .14, $p < .05$). Lower levels of infant cortisol (*B*= -.22, p =.06) were also marginally associated with higher levels of dysregulation problems.

Combined Path Model 2 (AUCg difference cortisol). The second model for the third aim utilized a difference score for area-under-the-curve with respect to ground (AUCg) approach for measuring cortisol attunement (Table 18; Figure 10). Like the previous models, all other manifest variables were included in one comprehensive model of synchrony and associations with later SE problems. Again, most findings remained consistent with some minor changes. Lower levels of flexibility within nonnegative engaged states was associated with more externalizing problems (*B* = -.26, SE = .13, $p < .05$). Shorter durations in nonnegative engaged states were associated with higher internalizing problems (*B* = -.38, SE = .15, $p < .05$). Greater overall flexibility was associated with more internalizing (*B* = .37, SE = .15, $p < .05$) and dysregulation (*B* = .44, SE = .15, $p < .01$) problems. Finally, and of note specific to this model, smaller AUCg differences were associated with higher levels of internalizing (*B* = -.27, SE = .12, $p < .05$) and dysregulation (*B* = -.36, SE = .12, $p < .01$) problems.

To examine the combined relations of all synchrony domains, a measurement model of a latent factor with all global CIB, micro SSG, and cortisol variables was tested.

This single factor measurement model did not converge. To further explore relations between synchrony measures, a "behavioral synchrony" factor was also estimated, which included global CIB and micro SSG measures, but not cortisol measures. Using modification indices to improve model fit, this model (Table 19) had adequate fit (χ^2 (17, *N* = 323) =24.49, *p* = .09; RMSEA = .04; CFI = .98; SRMR = .05).

Next, a path model was estimated for behavioral synchrony, mother cortisol, and infant cortisol in association with BITSEA. The two approaches for measuring cortisol were tested separately in different variations of the model: individual trait measures for mother and infant (Table 20; Figure 11); and the AUCg absolute difference score (Table 21; Figure 12). First, the model using trait cortisol did not meet criteria for adequate fit (χ^2 (172, *N* = 323) = 346.17, *p* < .001; RMSEA = .06; CFI = .91; SRMR = .07). Infant trait cortisol was positively associated with mother trait cortisol (*B* = .27, SE = .08, *p* < .001), and marginally associated with BITSEA (*B* = -.27, *SE* = .14, *p* < .10). Subsequent variations of models using this "behavioral synchrony" measure tended to have less than adequate fit and did not reveal any associations with SE problems, with the exception of prenatal depression which as associated with higher BITSEA problems (*B* = .37, *SE* = .09, *p* < .001) . Next, regarding the model using AUCg difference for cortisol (Table 21; Figure 12), fit was better and adequate on most measures (χ^2 (63, *N* = 323) = 80.58, *p* =.07; RMSEA = .03; CFI = .97; SRMR = .07). Still, only prenatal depression significantly predicted BITSEA (*B* = .37, *SE* = .09, *p* < .001). Although behavioral synchrony was not associated with BITSEA, cortisol AUCg difference was marginally associated with BITSEA, such that higher differences were associated with lower BITSEA (*B* = -.29, *SE* = .16, *p* < .01).

Summary

Data analyses required substantial exploration, cleaning, and condensing to establish a dataset that minimized confounding variables and nonnormal distributions while representing meaningful constructs of the mother-infant dyadic relationship at twelve weeks postpartum. Results indicated that latent factors of synchrony were generally not supported by measurement models nor path models due to poor loading misspecification and model fit. In contrast, manifest variable path models tended to have good fit across each domain of synchrony, including global, microanalytical, and physiological observation methods.

Additionally, individual path models of separate areas of micro and cortisol synchrony were each associated with later child SE problems, but global observation was not associated with child SE problems. Two approaches for measuring cortisol manifest variables were tested, including difference scores based on absolute differences between post-task samples as well as AUCg. Cortisol results remained generally consistent, that greater differences between mother and infant cortisol were associated with fewer internalizing and dysregulation problems. When the three domains of synchrony at T1 were combined in a single, multivariate path model, global reciprocity, NNE duration, overall flexibility, predictability, and cortisol were associated with at least one category of child SE problems at T2. These findings indicate that the most appropriate models to examine synchrony observations and their association to subsequent child SE problems were manifest variable models that tested all three domains of synchrony in relation to separate areas of SE problems (figures 10 and/or 11).

DISCUSSION

The direct comparison of observational approaches to measuring dyadic behavior is critical to the advancement of developmental, clinical, and social psychology. Although synchrony is widely identified as a crucial characteristic of the parent-child relationship, no single method has been identified as a universally accepted standard for detecting and assessing the quality and nature of synchrony (Delaherche, 2012). This study builds on existing research by integrating multiple methodological approaches to characterize parent-child behavior and mental health using in-home observational, physiological, and mother-report data. Findings from this study suggest that the measurement of synchrony can be multidimensional, and include larger global observations of the quality of behavior, dynamic behavior patterning, and cortisol trait and attunement. In addition, synchrony in mothers and their infants appears to reflect a mutual, contingent, and flexible pattern of behavior across an interaction. Physiological HPA activation and dyadic attunement were related to aspects of synchrony, but these processes may operate differently than previously thought. Finally, synchrony from behavioral and physiological perspectives was related to the emergence of infants' social-emotional competence, with some differential specificity in its effects that depended on the profile of synchrony characteristics.

Findings indicated that observed dyadic behavior, even when assessed across methods, was inter-correlated. Cortisol, however, was somewhat less consistent in its associations with key variables. Connections to later social-emotional problems in infants tended to emerge once multiple synchrony constructs were examined in conjunction with one another. Although related with one another, the various characteristics of synchrony did not cohere together as a single construct of synchrony, and associations with infant social-emotional problems were weakened substantially. Thus, various measurement approaches tended to provide unique detail regarding synchrony, and did so in an additive manner. Comparison of methodological strategies for understanding synchrony enables the development of a more nuanced understanding of the critical aspects of the mother-infant relationship in the early postpartum period.

Associations of Behavior within Domains

The first aim was to examine whether synchrony examined from micro, global, and physiological were associated with one another within domains. Behavioral approaches to examining dyadic behavior were consistently associated with one another regardless of whether the synchrony construct involved more microanalytic or global approaches. This suggests that there are important conceptual similarities between global and micro approaches of measuring synchrony. The one exception to this was the microanalytic index of average duration in nonnegative engaged states, which was not associated with global approaches. Duration in nonnegative engagement was, however, related with other micro-analytical measures of flexibility and predictability. Perhaps this duration measure is not an accurate representation of synchrony because it represents a more concrete, objective, or quantitative aspect of dyadic behavior that is less evaluative of the quality of interaction. Thus, more or less time being engaged with one another in a neutral or positive affect may not necessarily suggest a reciprocal, fluent, adaptive, or child-oriented relationship.

Despite moderate to high associations within domain and across observation systems (e.g., global associated with other global as well as global associated with micro characteristics), examination of synchrony variables as individual latent constructs yielded inconsistent results. First, global measures of reciprocity, fluency, and child-led behavior fit well as a latent construct, consistent with previous work using these dyadic measures of behavior from the CIB system as a composite for synchrony, mutuality, etc (e.g., Feldman 2012). However, microanalytic measures hypothesized to relate to synchrony did not consistently fit a synchrony factor. Similarly, dyadic "trait" cortisol did not fit as a single latent factor that incorporates both mother and infant cortisol over time. Instead, infant and mother trait cortisol constructs were only successful when formed separately, suggesting that trait cortisol may not be consistently attuned between mothers and infants at infant age twelve weeks. Thus, for both microanalytic and physiological domains, the various measures of synchrony provide unique detail that is not consistently related to other aspects of synchrony for a dyad. Likewise, the attempt to combine synchrony constructs across global, micro, and physiological domains as a single construct to predict child social-emotional problems (Aim 3) was unsuccessful. Since the measurement models for micro and physiological characteristics did not fit well as latent constructs within their respective areas, it is not surprising that a single uniform "synchrony" factor did not adequately fit the observations from the present study. It seems apparent that multiple approaches and measures of the dyadic relationship should be examined independently, but also in conjunction, to effectively characterize synchrony.

Another important finding was that maternal cortisol was not related to any dyadic behavior, whereas infant cortisol at P2 and P3 (post-tasks) was related to observed behavior. Higher infant cortisol at these periods was indicative of lower reciprocity and fluency, perhaps indicating that infant physiological arousal could be interfering with a positive, engaged dyadic relationship, or vice versa. Some have suggested that the underlying mechanisms of physiological attunement may be related to the mechanisms that underlie behavioral synchrony (e.g., Sethre-Hofstad et al., 2002; Bright, Granger, & Frick, 2011). However, findings suggest that this may be driven by infant cortisol, which could influence dyadic behavior in multiple ways. Physiological dysregulation related to stress may identify the level of sensitivity to stress within an individual or a dyad, evidenced by elevations in cortisol as well as other physiological signs such as EEG asymmetries and observable emotional withdrawal (Sanchez et al., 2001; Goodman, 2007).

Mother and infant cortisol levels were linked, but only consistently so within the same sample time point (e.g., mother P1 with infant P1, mother P2 with infant P2, etc). This finding diverges somewhat from previous research on attunement, which has found modest to strong positive correlations (e.g., Granger et al., 1998; Hibel, Granger, Blair, & Cox, 2009; Laurent, Ablow, & Measelle, 2012; Sethre-Hofstad, Stansbury, & Rice, 2002). In fact, the strength of this connection has led some to argue that the strongest predictor of infant HPA axis activity may be that of their mothers rather than their own diurnal rhythm (Bright, Granger, & Frick, 2011). However, attunement for infants at the young age of twelve weeks old is less well known; in fact, very little is known regarding infant cortisol levels, reactivity, and diurnal rhythms and their relation to those of their mothers. Still, one study examining cortisol levels in young infants (ranging from 6 to 24 weeks of age) found consistent attunement with their mothers during physical holding (Neu, Laudenslager, & Robinson, 2009) although more in-depth examination of specific ages and contexts is warranted to establish the developmental nature of these phenomena (Bright, Granger, & Frick, 2011).

Although many observational studies of behavior in parent-child dyads have historically selected coding methods based on availability of resources, theoretical issues, and the empirical questions at hand, multiple coding systems used within studies allows for a richer characterization of behavioral constructs. The importance of comparing multiple coding schemes has been outlined by Margolin (1998), who notes that it allows observation from multiple perspectives and encourages creativity in thinking about the nature of family relationships. Global and micro coding systems differ on the complexity of behavior captured as well as the size of the coding "unit" (e.g., event or "bout") of interest (Margolin, 1998). An important consideration for developing a coding scheme for synchrony was suggested by Cappella (2005), who recommended that investigators identify what should be observed (coding), how to represent data of observations, and the frequency of making observations. Some have achieved this by examining "micro-units" of behavior (e.g., Condon & Sander, (1974); Cappella, 2005), whereas others have utilized a "judgment method", or global coding (Delaherche, 2012). However, Delaherche (2012) notes several disadvantages to global coding methods, despite the logisitical advantages of faster, more efficient coding. In particular, the judgment of even skilled, well-trained coders may be questionable, especially when addressing the concept of synchrony, which has had varying definitions without a single accepted definition. On the other hand, even more standardized methods for assessing synchrony are difficult to achieve without the clinical judgment of observers. In many studies, methods are tested based on the ability to predict specific outcomes of interest in conjunction with manually annotated methods (Delaherche, 2012).

The convergence of multiple observational approaches to examine similar constructs provides robust support for salient behaviors, such as negativity (e.g., Jacob & Krahn, 1987), whereas differences in findings between systems may provide more detail regarding the characteristics of behavior within larger or more specific contexts (Floyd, O'Farrell, & Goldberg, 1987). Global systems have been consistently correlated with microanalytic coding, such as the CIB "reciprocity" variable related to synchrony in microanalysis (Moshe & Feldman, 2006; Harel, 2006) When consistent across multiple systems and with existing literature, the use of new observational systems strengthens findings (Margolin, 1998). However, the challenge is understanding discrepancies when they occur, which could be due to subtle methodological differences or truly divergent characteristics of behavior. Feldman (2012) has suggested that the language and methodologies for coding behavior are important for developing a solid foundation for measures of relationships with a bottom-up theoretical approach.

Prospective Associations of Synchrony Constructs with Child SE Problems

The second aim was to examine prospective relations between synchrony and subsequent emerging social-emotional problems. Using comparative methods for studying the early parent-child relationship offers a more complete perspective of social emotional development (Feldman, 2012). Reciprocity, nonnegative engagement, flexibility, and cortisol attunement were found to be prognostic of the emergence of child social-emotional problems, although some associations occurred in the opposite direction as hypothesized. The finding that multiple measures of synchrony are potentially influential to social-emotional functioning during this early infancy stage in the first few months of life is consistent with previous research, which has linked mutuality, intersubjectivity, and synchrony with better infant development (Feldman, 2007b).

Global Behavioral Synchrony. Within global approaches to observing behavior, reciprocity was key in its relation to subsequent SE problems in children, but only after accounting for aspects of behavior and physiology from global and physiological domains as well. Thus contrary to hypotheses, reciprocity on its own, even after accounting for fluency and infant-led interaction, did not predict SE problems. The failure to find a connection between global synchrony and infant SE problems is unexpected. Global scales have identified aspects of the early environment that promote or threaten the infant's later functioning, such as attachment security, IQ, behavior problems, self-regulation, and social competence, among others (Ainsworth et al., 1978; Feldman, 2007b). Global observation of face to face synchrony and coordination between six and twelve weeks postpartum has predicted positive outcomes such as self-regulation, symbolic skills, and empathy (Feldman, 2007a). One potential consideration is that the characteristics selected were not sufficiently sensitive to variations in dyadic behavior. For example, some studies have operationalized synchrony as a combination of dyadic and individual measures of maternal and infant behavior, such as high mother acknowledging and low intrusiveness as well as high infant positivity and low withdrawal (Keren, Feldman, & Tyano, 2001). Another possibility is that the global measures lacked specificity in characterizing the influential aspects of the early mother-infant relationship at the early stage of 12 weeks postpartum. For instance, Feldman (2007b) suggests that contingent, reciprocal behavior, particularly on the part of the infant, emerges and increases over the first year of life.

In addition, parents from more communalistic societies tend to be more didactic with children compared to those from individualistic societies (Ispa, 2004). During this task with the goal of teaching a skill, for example, mothers may have been more likely to break their usual parental behavior in order to comply with the task demands. This would result in less sensitive parenting which may reduce ratings of reciprocity, fluency, and child-led behavior. It should also be considered that the failure to identify meaningful relations between fluency and adaptation-regulation may be due to weak effects that did not reach significance or simply an anomalous occurrence limited to the present study.

Microanalytic Behavioral Synchrony. Microanalytic coding systems provide the opportunity to examine in detail the temporal patterning as well as contextual content of dyadic behavior as it unfolds. Regarding micro coding approaches, nonnegative engagement and flexibility were key to predicting SE problems. Patterns of dyadic synchrony using micro methods were most consistently associated with all SE problems compared to global measurement, highlighting the utility and value of micro coding in parent-child research. First, nonnegative engagement was a meaningful predictor of SE problems, specifically the average duration in such states. Although NNE duration was not associated independently with other measures of behavior nor any SE problems, once included in a larger model which accounted for multiple aspects of the relationship, shorter mean duration in each nonnegative engaged state was associated with greater internalizing problems. Nonnegative engagement was hypothesized to represent a synchronous state due to its content, which consists of shared, mutual social engagement as well as a neutral or positive affect. Duration of synchrony provides the opportunity to quantify the proportion of time in an attuned, affectively engaged state for the dyad. Longer duration of time spent in nonnegative engaged states appears to be beneficial and may build self-regulatory skills essential to positive mental health functioning as children grow. Thus, mutuality between dyads, specifically in a shared engaged and neutral or positive affect, promotes healthier infant SE development (Lunkenheimer, Albrecht & Kemp, 2012). Of note, the frequency of shared positivity was very low and unrelated to other measures; therefore, it appears that at this early infant age, non-negativity may be more indicative of a developmentally and socially beneficial state between mother and infant, compared to a specifically positive affective state. Observation of infant positivity appears to be less consistent and less frequent during interactions. For instance, Belsky (1991) found higher stability and higher frequency in negativity compared to positivity in infants at both ages 3 months and 9 months. Similarly, Lunkenheimer and colleagues (2012) found no relation between dyadic positivity and child behavior problems, but instead identified flexibility as a salient predictor of risk for child psychopathology.

Flexibility as a Critical Predictor of Social Emotional Competence. An important aspect of the mother-infant relationship that was consistently associated with SE problems was flexibility, measured from a microanalytic perspective. Dyads with higher flexibility only within the nonnegative engaged states tended to have fewer externalizing and dysregulation problems, with a similar trend approaching significance for internalizing problems. However, higher levels of flexibility across all states of behavior, which included negative and/or unengaged states, were associated with higher levels of internalizing and dysregulation problems. This finding identifies the importance of context and content within dyadic interactions; patterning of behavior alone does not necessarily identify developmentally beneficial or harmful processes. Instead, flexibility may either increase or risk for subsequent difficulties with social and emotional competence later in childhood. Although flexibility has generally been identified as beneficial and adaptive for dyads (e.g., Hollenstein, Granic, Stoolmiller, & Snyder, 2004; Lunkenheimer et al., 2012), some have argued that flexibility in certain contexts may be indicative of disorganized transitions in a system that could result in negative outcomes (e.g., Dishion, Forgatch, Van Ryzin, & Winter, 2012), but examination of these patterns during infancy is needed. In the present study, it appears that mothers and infants who shift easily between various states of engagement and affect, but who do not tend to shift into negative or unengaged states, tend to have fewer infant SE problems at one year of age.

A flexible system is likely to more readily to adapt to fluctuating contextual demands, in contrast to a rigid system which may not be as prepared to change and is therefore less adaptive (Hollenstein, 2012). In contrast, family rigidity may be indicative of the "enmeshed" family, in which members are generally not encouraged to be autonomous and each member must compete for attention, with a tense and didactic atmosphere (Feldman, 2012). Family patterns of flexibility, as opposed to those that are characterized by rigidity, are considered stable from infancy through toddlerhood and have been associated with children's social competence in later childhood (Feldman & Masalha, 2010). In total, research to date supports a conceptualization that synchrony, characterized by coherent, flexible, and mutually engaged behavior, may be a key mechanism underlying effective social emotional competence. Flexibility appears to be a consistent, powerful characteristic of the parent-child relationship associated with the emerging social and regulatory skills in children. Whereas other observations, such as reciprocity, may be inconsistent or contingent upon specific other contextual considerations, the microanalytical measure of flexibility provides clear identification of SE risk in children.

Physiological Attunement. At its core, synchrony is believed to represent both a physiological as well as a behavioral process of mutual attunement (Feldman, 2007b). A dynamic systems perspective also presumes that biology and environment converge and interact to result in the dyadic system of each pair (Hollenstein, 2012). The incorporation of physiological measures of attunement is key to better understanding the nature of mother-infant synchrony. Developmental science has become more focused on individual differences in the psychobiology of the stress response, which may serve as an index of risk or resilience (Boyce & Ellis, 2005; Bright, Granger, & Frick, 2011). Cortisol provides an index of HPA stress response and general activity due to its sensitivity to environmental demands. For example, behavioral inhibition has been linked to elevated cortisol secretion, high and stable heart rates, and increased auditory startle responses (Fox, Rubin, Calkins, Marshall, Coplan, Porges, Long, & Stewart, 1995; Schmidt, Fox, Schulkin, & Gold, 1999). Mother-infant physiological attunement has been well documented, and is speculated to occur due to a mother's sensitivity and responsiveness to her infant's emotional and physiological state (e.g., Sethre-Hofstad et al., 2002). The mother-infant attachment relationship as well as maternal sensitivity are likewise associated with infant stress reactivity (Blair et al., 2006; Spangler & Grossmann, 1993; Spangler, Schieche, Ilg, Maier, & Ackermann, 1994).

In the current study, not only did behavioral synchrony link to subsequent SE problems in infants, physiological measures were also associated with SE problems. However, individual mother and child trait cortisol as well as dyadic attunement of cortisol were not well matched. Contrary to previous literature, higher latent infant trait cortisol was associated with *lower* levels of externalizing problems. Moreover, dyads with more attuned salivary cortisol levels tended to have children with *higher* internalizing and dysregulation problems, even after accounting for the positive relation between mother and infant trait cortisol. This unexpected association suggests that lower reactivity as well as closer attunement may be indicative of a maladaptive and higher-risk HPA system, which may lead to adverse developmental outcomes.

The finding that infant cortisol, but not maternal cortisol, was related to externalizing problems highlights the complexity of physiological reactivity to stress, which is likely influenced by multiple mediating and moderating variables. Importantly, not all infants, particularly at twelve weeks of age, show a cortisol response to psychological stressors (Beijers, Riksen-Walraven, & de Weerth, 2010), but instead respond according to specific individual differences (Gunnar & Donzella, 2002), such as the attachment relationship (e.g., Nachmias et al., 1996). For instance, higher cortisol reactivity is considered to indicate heightened responsiveness to the environment, known as “biological sensitivity to context” (Boyce & Ellis, 2008; Ellis & Boyce, 2005; Ellis, Essex, & Boyce, 2005), which can result in negative health outcomes in the presence of stressful or adverse environments or beneficial effects in response to healthy, supportive environments. Heightened sensitivity to the immediate context is believed to occur due to developmental plasticity of stress response systems, which enable individuals to adapt to their specific circumstances (Boyce & Ellis, 2005). (Goodman, 2007). From this perspective, higher cortisol responsivity may not always be indicative of poor functioning.

This sensitivity has been linked to other developmental vulnerabilities in the form of stress-related psychopathology. Paradoxical suppression of HPA activation has been observed under stressful conditions, and children with temperaments characterized as shy or introverted tend to have attenuated cortisol reactivity to typical life stressors (Davis, Donzella, Krueger, & Gunnar, 1999; de Haan, Gunnar, Tout, Hart, & Stansbury, 1998). Unexpectedly, children exposed to chronic stress and/or neglect, such as those in Romanian orphanages (Carlson & Earls, 1997), or living near the epicenter of a major earthquake (Najarian, L. M., & Fairbanks, 1996), have demonstrated lower waking cortisol levels and flattened diurnal cortisol rhythms (Boyce & Ellis, 2005). Emotional abuse and PTSD has been associated with reduced, rather than elevated levels, of cortisol (Yehuda et al., 2001). Some have speculated that the stress response system may, at times, dampen physiological effects rather than amplify them (Munck, 1989) and downregulate the HPA axis (Boyce & Ellis, 2005; Munck, Guyre, & Holbrook, 1984).

Contrary to expectations, smaller differences in AUCg cortisol levels, which was conceptualized as attunement in the present study, did not predict reduction of social-emotional problems in infants. The finding that, instead, greater differences were associated with *reduced* symptoms instead may be difficult to interpret because it is confounded by the inability to identify of the direction of the difference in cortisol (higher mother/lower infant vs. higher infant/lower mother). Perhaps the majority of the dyads tended to have infants with higher cortisol than mothers. This seems to highlight the importance of soothing a negative child without becoming distressed as well. For example, a child who has become stressed and more activated by stressors, but who can then be soothed by a mother who is not physiological aroused by her distressed infant, may learn to self-regulate more effectively than infants who are not as easily aroused or infants whose mothers attune to infant distress physiologically. In contrast, mothers who become stressed by the infant's arousal and match cortisol levels may then enter a coercive cycle with their infants which can in turn perpetuate a highly aroused distressed state. Such an occurrence is consistent with Shaw and colleagues' (2000) "early starter model" for antisocial behavior, adapted from coercion theory (Patterson, 1982). According to this perspective drawn from attachment theory, early antecedents to coercive relations would be dyads in which an irritable infant exhibits high demands and a mother is unable to respond to her infant's needs in an effectively contingent and sensitive manner (Shaw et al., 2000). When an infant becomes stressed and unhappy, effective attunement should perhaps be characterized by maternal empathy and sensitivity, but not necessarily matching of stress response systems.

Generally, research on mother-infant physiological attunement finds that dyads are consistently attuned and that this tends to be related to positive aspects of health and relational functioning (Bornstein, 2013). However, others have identified important moderators of such relations. For example, Skowron and colleagues (Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman (2013) identified caregiver maltreatment as a moderator influencing toddlers' resting sinus arrhythmia (RSA) and inhibitory control in a challenging task. In addition, Brummelte and colleagues (2010) found that infant cortisol was only correlated with maternal behavior among extremely preterm infants, compared to full-term infants. These findings support theory and research on the importance of examining the influence of the early social/caregiving environment, allostatic load, and other factors to better understand the dynamics of regulatory systems (e.g., Gunnar, Frenn, Wewerka, & Van Ryzin, 2009; McEwen, 2006; Pollak, 2008; Porges, 2003). Perhaps a subset of children in this study who showed elevated cortisol were demonstrating an appropriate stress response to a challenging task, whereas some of those without elevations in cortisol may have been exposed and primed by a stressful environment. With respect to attunement, the connection between infant cortisol and mother-child behavior may be indicative of infants who are more sensitive to the environmental context. Thus, higher attunement at young infant ages may identifies infants who are more susceptible to the world in which they live, which could be damaging for infants growing up in a chaotic and unstable or negative environment, but could also be particularly beneficial for those in a stable, secure home environment.

Methods for examining synchrony and its related constructs (e.g., mutuality, contingency, and intersubjectivity) have varied from study to study, but links to SE development have been relatively consistent. For example, mutual dialogue between mothers and infants was associated with better self-regulation in the preschool years (Feldman, 2007b). Similarly, synchrony with both mother and with father at 3 months was related to lower levels of behavior problems at age 2 (Feldman & Eidelman, 2004). This connection is hypothesized to be related to the promotion of social and emotional self-regulatory capacities, which in turn sets the stage for healthier, more adaptive functioning. The concept of self is essentially formulated from the social environment, which encourages the ability to regulate internal states, internalize moral norms and follow social rules (Feldman, 2007b; Kopp, 1982).

Implications for the Parent-Child Relationship

Methodological considerations aside, synchrony is an important characteristic of the early mother-infant relationship that is critical for the acquisition of social and emotional competence emerging in the first year of life. At its core, synchrony is a descriptor of a combination of important social and regulatory skills which emerge within a dyad, including contingency, reciprocity, empathy, and communication. It reflects a dynamic process that requires consideration of the interaction between both members of the dyad, and is inextricably linked to the constantly shifting, updating exchange between mothers and infants (Bornstein, 2013). Effective synchrony, characterized by mutually neutral or positive affect, engaged, and flexible behavior, lays the foundation for infants to learn to self-regulate and make sense of the social world. These skills set the stage for infants' later mental health functioning. When synchrony is poorer in quality or less frequent, children may be at risk to develop more externalizing, internalizing, or dysregulated symptoms which could lead to diagnosable disorders as children enter early childhood and beyond.

A key consideration for this area of study is that synchrony is a dynamic process involving both internal and external influences on the dyad. Thus, the quality of synchrony is dependent on an effective match between both members' needs, level of sensitivity to partner, and own communicative signals. As a dynamic concept, it is presumed that the genetics, temperament, physical health, outside environment, and a multitude of other factors contribute to synchrony between a mother and her infant. For instance, an infant with a highly reactive, fussy temperament who is chronically ill and highly demanding may be less responsive to its mother's attempts to soothe and engage her child (Shaw et al., 2000). Similarly, a mother with high levels of stress, her own physical illness, or depression, may be less sensitive or effectively responsive to her infant's needs (Goodman, 2007). Therefore, it is possible that synchrony does not necessarily influence or cause infant social-emotional competence *per se*. Instead, synchrony could be considered a product of and mediator for the myriad state- and trait-related elements that influence behavior as well as subsequent mental health. Regardless of its conceptualization however, present findings highlight the importance of effective synchrony as a critical characteristic of a healthy parent-child relationship.

Contextual Considerations

Given the characteristics of the present sample, sociodemographic elements such as cultural origin, income, and education may have played a role in the findings. However, results did not change after covarying for such characteristics. Synchrony and social-emotional development may, to a great extent, be universal across contexts. For instance, the global CIB coding system has been validated across the U.S., Brazil, Italy, France, Germany, Belgium, Israel, and the U.K. (Feldman, 2007b). Nonetheless, it is likely that some components of mother-infant relationships are universal while others may vary depending on context. Further examinations which replicate studies and directly compare populations will be needed to better understand where the similarities and differences lie.

Another important context of the present study is the early postpartum period. The mother-infant relationship was examined at infant age 12 weeks because it appears to be the first age at which synchrony tends to emerge (Feldman 2007b). Importantly, this beginning stage of synchrony may serve as a critical period for the development of a healthy mother-child relationship. Synchrony characterized by reciprocity, time lag, and infant led behavior appears to be highly sensitive to biological risk, such as premature birth or physical illness, as well as the environment of caregiving (Feldman, 2007b; Feldman, Greenbaum, Yirmiya, & Mayes, 1996; Feldman, Greenbaum, & Yirmiya, 1999).

Clinical Implications

Synchrony may serve as an important index of the early parent-child relationship that identifies risk, as well as foci for various intervention approaches. Synchrony can be influenced by various risk factors but can also create and contribute to problematic outcomes for parents and children. When risk is present in a dyadic relationship, synchrony is consistently reduced (Feldman, 2007b). In studies comparing clinic-referred versus non-referred families to an infant mental health clinic, patterns relating to dyadic synchrony are poorer on all measures in the clinic-referred group. These included lower maternal sensitivity and higher intrusiveness, lower child engagement and higher child withdrawal, and lower dyadic reciprocity (Keren, Feldman, & Tyano, 2001). More subtle differences are also found in families with sub-clinical levels of difficulty, such as chronic depressive symptomatology (Weinberg & Tronick, 1998). Specific screening and diagnostic tools targeting synchrony, therefore, could be clinically useful to identify at-risk families for both prevention of further problems as well as identification of psychopathology.

Present findings suggest some level of specificity in predicting the area of difficulty in infant's social-emotional development, including externalizing, internalizing, and dysregulation problems. For instance, a profile with rigidity in nonnegative engaged states alone identify risk for externalizing problems, but the addition of overall disorganized patterns of affect and engagement may be indicative of a profile specifying dysregulation problems, whereas another profile involving less time spent in nonnegative engaged states and more disorganized overall behavioral patterns may indicate internalizing problems. Thus, targeted, multidimensional approaches to examine characteristics of synchrony have the potential to identify unique relational profiles of early specific psychiatric disorders (Feldman, 2007b). Adding physiological indicators of risk adds an additional layer of screening and diagnosis; for instance, dyads in which both mother and infant have high cortisol levels, in addition to poor behavioral synchrony may be identified as at-risk for mental and physical health problems. Continuing research aimed to more clearly define profiles underlying individual diagnoses can improve differential diagnosis and inform intervention efforts.

Limitations and Future Directions

Although this study has the potential to advance knowledge regarding the nature of dyadic relationships and infant social-emotional development, there are several limitations to be considered. First, the sample examined was drawn from a specific population with unique characteristics, such as Mexican American ethnicity, low income, and low education level. This can introduce specific risk and cultural questions that may not be applicable to the broader population. Second, the outcome measures, drawn from a mother-reported questionnaire, could be susceptible to reporting bias by mothers.

Nonetheless, a strength of this study was the utilization of multiple measurement methods in observing synchrony in vivo as well as using physiological indicators. To control for negativity bias, maternal depression and demographic covariates were incorporated into analyses. Finally, many of the methods used for the present study are still undergoing development and testing to identify appropriate "gold standards". For instance, state space grids are still being explored as a means of understanding the temporal patterning of behavior; however, no single approach has been identified to best characterize synchrony between dyads. This study attempted to address these shortcomings by separating behavior based on content and focusing solely on mutual, nonnegative engaged behavior in mothers and infants.

In particular, approaches for cortisol attunement in dyads have not been well established. This study attempted two approaches, trait variables and difference scores, to attempt to measure attunement between mothers and infants. Still, additional work is needed in the field to better explicate the best practices for examining salivary cortisol in dyads. Further, trait cortisol was examined, but insufficient data was available to parse out its effects in comparison to state cortisol. With repeated measures built into the larger study, estimating state cortisol will be possible in the near future and should be examined within a full state-trait model to better understand aspects contributing to cortisol in individuals. The absolute difference score for AUCg between mothers and infants also does not allow for curvilinear effects of differences; that is, large differences in which infants are higher than mothers are viewed identically as dyads with large differences in which mothers are higher than infants. Future work will be needed to examine interactions and possible curvilinear effects of mother-infant cortisol trajectories.

Conclusion

Efforts to clearly define synchrony and its most salient characteristics will help provide important answers to questions regarding the means through which the early mother-infant relationship shapes the mind and body of a developing child. Feldman (2007b) has argued that bottom-up approaches of defining behavior through context-dependent, comparative, and careful scientific inquiry is needed to explicate the nature underlying social emotional development. A dynamic perspective of addressing such questions may be the best approach because it presumes that nature and nurture are occurring in constant interaction rather than attempting to glean individual influences of traits, states, and environment from the larger whole (Hollenstein, 2012). The “dance” of shared dialogue between mother and infant, therefore, becomes deeply integrated into the developing self (the “dancer”) within the infant (Feldman, 2007b). Synchrony, therefore, may be the ideal focus for future parent-child research because it has the potential to effectively integrate multiple critical characteristics of the state, trait, physiological and environmental factors that undoubtedly shape children’s social emotional growth.

REFERENCES

Ainsworth, M. D. S., Blehar, M., & Waters, E. Wall. S. (1978). Patterns of attachment. HiIlsciale, *NJ: Erl baum.*

Ainsworth, M. D., Blehar, M. C., Waters, E., & Wall, S. (1978). *Patterns of attachment: Assessed in the strange situation and at home.* Hillsdale, NJ: Erlbaum.

Bayley, N. (2006). Bayley *Scales of Infant and Toddler Development: Bayley-III*. Harcourt Assessment, Psych. Corporation.

Beebe, B. B. (2000a). Coconstructing Mother—Infant distress: The microsynchrony of maternal impingement and infant avoidance in the face-to-face encounters. *Psychoanalytic Inquiry*, *20*(3), 421.

Beebe, B. B. (2000b). Systems models in development and psychoanalysis: The case of vocal rhythm coordination and attachment. *Infant Mental Health Journal, 21*(1-2), 99-122.

Beebe, B., Jaffe, J., & Lachmann, F. (1992). A dyadic systems view of communication. In N. Skolnick, & S. Warshaw (Eds.), *Relational perspectives in psychoanalysis* (pp. 61-81)

Bell, D. C., & Bell, L. G. (1989). Micro and macro measurement of family systems concepts. Journal *of family psychology,* 3(2), 137.

Belsky, J., Fish, M., & Isabella, R. A. (1991). Continuity and discontinuity in infant negative and positive emotionality: Family antecedents and attachment consequences. Developmental *Psychology*, 27(3), 421.

Bergman L.R., M., D. (1997). A person-oriented approach in research on developmental psychopathology. *Development and Psychopathology, 9*(02), 291.

Blair, C., Granger, D., Willoughby, M., & Kivlighan, K. (2006). Maternal Sensitivity Is Related to Hypothalamic-Pituitary-Adrenal Axis Stress Reactivity and Regulation in Response to Emotion Challenge in 6-Month-Old Infants.*Annals of the New York Academy of Sciences*, 1094(1), 263-267.

Bornstein, M. H. (2013). Mother–Infant Attunement. In Legerstee, & Bornstein (eds). *The Infant Mind: Origins of the Social Brain*, 266.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. Development *and psychopathology*, 17(2), 271-301.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. Development *and psychopathology*, 17(2), 271-301.

Bråten, S. (2009). *The intersubjective mirror in infant learning and evolution of speech.* John Benjamins.

Brazelton, T. B., & Koslowski, B., & Main, M.(1974). The origins of reciprocity: The early mother-infant interaction. The *effect of the infant on its caregiver*. *New York, NY: Wiley*, 49-76.

Briggs-Gowan, M. J., Carter, A. S., Irwin, J. R., Wachtel, K., & Cicchetti, D. V. (2004). The Brief Infant-Toddler Social and Emotional Assessment: Screening for social-emotional problems and delays in competence. *Journal of Pediatric Psychology, 29*(2), 143-155.

Briggs-Gowan, M. J., Carter, A. S., Skuban, E. M., & Horwitz, S. M. (2001). Prevalence of social-emotional and behavioral problems in a community sample of 1-and 2-year-old children. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*(7), 811.

Bright, M. A., Granger, D. A., & Frick, J. E. (2012). Do infants show a cortisol awakening response?. Developmental *psychobiology*, 54(7), 736-743.

Bright, M. A., Granger, D. A., & Frick, J. E. (2012). Do infants show a cortisol awakening response?. Developmental *psychobiology*, 54(7), 736-743.

Bronfenbrenner, U. (1989). Ecological system theories. *Ann. Child Develop.*, *6*, 187-249.

Cappella, J. N. (2005). Coding mutual adaptation in dyadic nonverbal interaction. The *sourcebook of nonverbal measures: Going beyond words*, 383-392.

Carlson, M., & Earls, F. (1997). Psychological and neuroendocrinological sequelae of early social deprivation in institutionalized children in Romania.*Annals of the New York Academy of Sciences*, 807(1), 419-428.

Carlson, V. V. J., & Harwood, R. L. (2003). Alternate pathways to competence: Culture and early attachment relationships. In S. M. Johnson, & V. E. Whiffen (Eds.), *Attachment processes in couple and family therapy.* NY, New York:Guilford Press.

Carter, A. S., Briggs-Gowan, M. J., Jones, S. M., & Little, T. D. (2003). The infant–toddler social and emotional assessment (ITSEA): Factor structure, reliability, and validity. Journal of abnormal child psychology, 31(5), 495-514.

Carter, S. C., & Keverne, E. B. (2002). The neurobiology of social affiliation and pair ponding. *Hormones, Brain and Behavior, 1*, 299-339.

Cauce, A. M., & Domenech-Rodríguez, M. (2002). Latino families: Myths and Realities. In J. M. Contreras, K. A. Kerns & A. M. Neal-Barnett (Eds.), *Latino children and families in the United States: Current research and future directions.* (pp. 3-25) Westport, CT, US: Praeger Publishers/Greenwood Publishing Group.

Chaudron, L. H., Kitzman, H. J., Peifer, K. L., Morrow, S., Perez, L. M., & Newman, M. C. (2005). Prevalence of maternal depressive symptoms in low-income Hispanic women. *J Clin Psychiatry, 66*(4), 418-23.

Cicchetti, D., & Schneider-Rosen, K. (1986). Theoretical and empirical considerations in the investigation of the relationship between affect and cognition in atypical populations of infants. In C. E. Izard, J. Kagan & R. B. Zajonc (Eds.), *Emotions, cognition, and behavior* (pp. 366-406). New York: Cambridge University Press.

Cohn, J. F., & Tronick, E. Z. (1983). Three-month-old infants' reaction to simulated maternal

Condon, W. S., & Sander, L. W. (1974). Neonate movement is synchronized with adult speech: Interactional participation and language acquisition. Science, 183, 99-103.

Cuellar, I. I. (1995). Acculturation rating scale for Mexican Americans-II: A revision of the original ARSMA scale. *Hispanic Journal of Behavioral Sciences, 17*(3), 275-304.

Davis, E. P., Donzella, B., Krueger, W. K., & Gunnar, M. R. (1999). The start of a new school year: Individual differences in salivary cortisol response in relation to child temperament. Developmental *psychobiology*, 35(3), 188-196.

de Haan, M., Gunnar, M. R., Tout, K., Hart, J., & Stansbury, K. (1998). Familiar and novel contexts yield different associations between cortisol and behavior among 2-year-old children. Developmental *Psychobiology*, 33(1), 93-101.

Delaherche, E., Chetouani, M., Mahdhaoui, A., Saint-Georges, C., Viaux, S., & Cohen, D. (2012). Interpersonal synchrony: A survey of evaluation methods across disciplines. Affective *Computing, IEEE Transactions on*, 3(3), 349-365.

Dickstein, S. S. (1998). Levels of family assessment: II. impact of maternal psychopathology on family functioning. *Journal of Family Psychology, 12*(1), 23-40.

Dishion, T. J., Forgatch, M., Van Ryzin, M., & Winter, C. (2012). The Nonlinear Dynamics of Family Problem Solving in Adolescence: The Predictive Validity of a Peaceful Resolution Attractor. Nonlinear *dynamics, psychology, and life sciences*, 16(3), 331.

Dixon, R. A., & Lerner, R. M. (1988). A history of systems in developmental psychology. In M. H. Bornstein, & M. E. Lamb (Eds.), *Developmental psychology: An advanced textbook* (2nd ed., pp. 3-50). Hillsdale, NJ: Erlbaum.

Dumas, J. J. E. (1995). "Balance of power": A transactional analysis of control in mother-child dyads involving socially competent, aggressive, and anxious children. *Journal of Abnormal Psychology (1965), 104*(1), 104-113.

Eisenberg, N., Cumberland, A., & Spinrad, T. L. (1998). Parental socialization of emotion. *Psychological Inquiry*, 9(4), 241-273.

Ellis, B. J., & Boyce, W. T. (2008). Biological sensitivity to context. Current *Directions in Psychological Science*, 17(3), 183-187.

Ellis, B. J., Essex, M. J., & Boyce, W. T. (2005). Biological sensitivity to context: II. Empirical explorations of an evolutionary–developmental theory.*Development and psychopathology*, 17(02), 303-328.

Evans, C. A., & Porter, C. L. (2009). The emergence of mother–infant co-regulation during the first year: Links to infants' developmental status and attachment. *Infant Behavior and Development*, 32(2), 147-158.

Feldman, R. (2006). From biological rhythms to social rhythms: Physiological precursors of mother-infant synchrony. *Developmental Psychology, 42*(1), 175-188.

Feldman, R. (2007a). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry*, *48*(3-4), 329-354.

Feldman, R. (2007b). Parent–Infant synchrony: Biological foundations and developmental outcomes. *Current Directions in Psychological Science: A Journal of the American Psychological Society*, *16*(6), 340-345.

Feldman, R. (2012). Parenting behavior as the environment where children grow. In Mayes, L., & Lewis, M. (Eds.). *The Cambridge Handbook of Environment in Human Development.* New York, NY: Cambridge University Press.

Feldman, R., & Eidelman, A. I. (2007). Maternal postpartum behavior and the emergence of infant-mother and infant-father synchrony in preterm and full-term infants: The role of neonatal vagal tone. *Developmental Psychobiology*, *49*(3), 290-302. doi:10.1002/dev.20220

Feldman, R., & Masalha, S. (2010). Parent–child and triadic antecedents of children's social competence: Cultural specificity, shared process.*Developmental Psychology*, 46(2), 455.

Feldman, R., Greenbaum, C. W., & Yirmiya, N. (1999). Mother–infant affect synchrony as an antecedent of the emergence of self-control. Developmental *Psychology*, 35(1), 223.

Feldman, R., Greenbaum, C. W., Yirmiya, N., & Mayes, L. C. (1996). Relations between cyclicity and regulation in mother-infant interaction at 3 and 9 months and cognition at 2 years. Journal *of Applied Developmental Psychology*, 17(3), 347-365.

Field, T. (1989). Sharing and synchrony of behavior states and heart rate in nondepressed versus depressed mother-infant interactions. *Infant Behavior & Development, 12*(3), 357.

Field, T. M. (1984). Early interactions between infants and their postpartum depressed mothers. *Infant Behavior & Development, 7*(4), 517-522.

Floyd, F. J., O'Farrell, T. J., & Goldberg, M. (1987). Comparison of marital observational measures: The Marital Interaction Coding System and the Communication Skills Test. Journal *of Consulting and Clinical Psychology,55*(3), 423.

Fogel, A. (1992). Movement and communication in human infancy: The social dynamics of development. *Human Movement Science, 11*(4), 387.

Fogel, A. (2007). Alive communication. *Infant Behavior & Development, 30*(2), 251.

Fogel, A., Walker, H., & Dodd, D. (2000). Beyond individuals: A relational-historical approach to theory and research on communication. *Il Rapporto Madre-Bambino.*

Ford, D. H., & Lerner, R. M. (1992). *Developmental systems theory: An integrative approach*. Newbury Park, CA: Sage.

Fox, N. A., Rubin, K. H., Calkins, S. D., Marshall, T. R., Coplan, R. J., Porges, S. W., ... & Stewart, S. (1995). Frontal activation asymmetry and social competence at four years of age. Child *Development*, 66(6), 1770-1784.

German, M. M. (2008). Familism values as a protective factor for Mexican-origin adolescents exposed to deviant peers. *The Journal of Early Adolescence, 29*(1), 16-42.

Gonzales, N. A., Knight, G. P., Morgan-Lopez, A., Saenz, D., & Sirolli, A. (2002). Acculturation and the mental health of Latino youths: An integration and critique of the literature. In J. Contreras, A. Neal-Barnett & K. Kerns (Eds.), *Latino children and families in the United States: Current research and future directions.* (pp. 45-74). Westport, CT: Praeger Publishers.

Goodman, S. H. (2007). Depression in mothers. Annu. *Rev. Clin. Psychol.*, 3, 107-135.

Gottlieb, G. G. (1991). Epigenetic systems view of human development. *Developmental Psychology, 27*(1), 33-34.

Granger, D. A. (1998). Children's salivary cortisol, internalising behaviour problems, and family environment: Results from the Concordia Longitudinal Risk Project. International *Journal of Behavioral Development*, 22(4), 707-728.

Granic, I. (2003). Dynamic systems methods for models of developmental psychopathology. *Development and Psychopathology, 15*(03), 641.

Granic, I., Dishion, T. J., & Hollenstein, T. (2006). The family ecology of adolescence: A dynamic systems perspective on normative development. In *Blackwell Handbook of Adolescence* (pp. 60-91) Blackwell Publishing Ltd. doi:10.1002/9780470756607.ch4

Guedeney, A., Guedeney, N., Tereno, S., Dugravier, R., Greacen, T., Welniarz, B…. Tubach, F. (2011). Infant rhythms versus parental time: Promoting parent–infant synchrony. *Journal of Physiology-Paris*, 105(4), 195-200.

Guendelman, S. S. (1990). Generational differences in perinatal health among the Mexican american population: Findings from HHANES 1982-84. *American Journal of Public Health (1971), 80*(suppl), 61-65.

Gunnar, M. R., & Donzella, B. (2002). Social regulation of the cortisol levels in early human development. Psychoneuroendocrinology, 27(1), 199-220.

Gunnar, M. R., Frenn, K., Wewerka, S. S., & Van Ryzin, M. J. (2009). Moderate versus severe early life stress: associations with stress reactivity and regulation in 10–12-year-old children. Psychoneuroendocrinology, 34(1), 62-75.

Haft, W. L., & Slade, A. (1989). Affect attunement and maternal attachment: A pilot study. *Infant Mental Health Journal*, 10(3), 157-172.

Halgunseth, L. L. C. (2006). Parental control in Latino families: An integrated review of the literature. *Child Development, 77*(5), 1282-1297.

Hane, A. A., Feldstein, S., & Dernetz, V. H. (2003). The relation between coordinated interpersonal timing and maternal sensitivity in four-month-old infants. *Journal of Psycholinguistic Research*, 32(5), 525-539.

Harel, H. (2006). Maternal representations, mother-infant interaction, and infant self-regulation in term and preterm infants. Ph.D. Ilan University.

Harrist, A. W., & Waugh, R. M. (2002). Dyadic synchrony: Its structure and function in children's development. *Developmental Review*, 22(4), 555-592.

Hibel, L. C., Granger, D. A., Blair, C., & Cox, M. J. (2009). Intimate partner violence moderates the association between mother–infant adrenocortical activity across an emotional challenge. Journal *of family psychology*, 23(5), 615.

Hollenstein, T., Granic, I., Stoolmiller, M., & Snyder, J. (2004). Rigidity in Parent—Child Interactions and the Development of Externalizing and Internalizing Behavior in Early Childhood. Journal *of abnormal child psychology,32*(6), 595-607.

Horwitz, S. M. C. (1998). Identification of psychosocial problems in pediatric primary care: Do family attitudes make a difference? *Archives of Pediatrics & Adolescent Medicine, 152*(4), 367.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural *Equation Modeling: A Multidisciplinary Journal*, 6(1), 1-55.

Hwa-Froelich, D. D. A. (2004). Three aspects of cultural influence on communication: A literature review. *Communication Disorders Quarterly, 25*(3), 107-118.

Ispa, J. J. M. (2004). Maternal intrusiveness, maternal warmth, and mother-toddler relationship outcomes: Variations across low-income ethnic and acculturation groups. *Child Development, 75*(6), 1613-1631.

Jacob, T., & Krahn, G. (1987). The classification of behavioral observation codes in studies of family interaction. Journal *of Marriage and the Family*, *49*(3), 677-687.

Jansen, J., Beijers, R., Riksen-Walraven, M., & de Weerth, C. (2010). Cortisol reactivity in young infants. Psychoneuroendocrinology, 35(3), 329-338.

Keller, H. (2000). Socialization for competence: Cultural models of infancy. *Human Development*, *46*(5), 288.

Kenny, D. A., Kashy, D. A., & Cook, W. L. (2006). *Dyadic Data Analysis.* The Guilford Press.

Keren, M., Feldman, R., & Tyano, S. (2001). Diagnoses and interactive patterns of infants referred to a community-based infant mental health clinic. Journal *of the American Academy of Child & Adolescent Psychiatry*, 40(1), 27-35.

Keren, M., Feldman, R., & Tyano, S. (2001). Emotional disturbances in infancy: diagnostic classification and interactive patterns of infants referred to a community-based infant mental health clinic. J *Am Acad Child Adolesc Psychiatry*, 40, 27-35.

Keren, M., Feldman, R., & Tyano, S. (2001). Emotional disturbances in infancy: diagnostic classification and interactive patterns of infants referred to a community-based infant mental health clinic. J *Am Acad Child Adolesc Psychiatry*, 40, 27-35.

Knight, G. (2009). *Studying ethnic minority and economically disadvantaged populations: Methodological challenges and best practices*

Kopp, C. B. (1982). Antecedents of self-regulation: a developmental perspective.*Developmental Psychology*, 18(2), 199.

Laurent, H. K., Ablow, J. C., & Measelle, J. (2012). Taking stress response out of the box: Stability, discontinuity, and temperament effects on HPA and SNS across social stressors in mother–infant dyads. Developmental *psychology*,*48*(1), 35.

Leckman, J. J. F. (2004). Primary parental preoccupation: Circuits, genes, and the crucial role of the environment. *Journal of Neural Transmission (Vienna, Austria: 1996), 111*(7), 753.

Legerstee, M., Markova, G., & Fisher, T. (2007). The role of maternal affect attunement in dyadic and triadic communication. Infant *behavior and Development*, 30(2), 296-306.

Lewis, M. M. D. (1999). A new dynamic systems method for the analysis of early socioemotional development. *Developmental Science, 2*(4), 457-475.

Lopez, M. L., Barrueco, S., & Miles, J. (2006). *Latino infants & their families: A national perspective & risk factors for development.* (A Report for the National Task Force on Early Childhood Education for Hispanics

Lunkenheimer, E. S., Albrecht, E. C., & Kemp, C. J. (2012). Dyadic Flexibility in Early Parent–Child Interactions: Relations with Maternal Depressive Symptoms and Child Negativity and Behaviour Problems. Infant *and Child Development,* 22 (3), 250-269.

Margolin, G. (1998). Effects of domestic violence on children. In Trickett, P.K., & Schellenbach, C.J. (Eds), (1998). *Violence Against Children in the Family and the Community* (pp. 57-101). Washington, DC, US: American Psychological Association, xi, doi: 10.1037/10292-003

Margolin, G., Oliver, P. H., Gordis, E. B., O'Hearn, H. G., Medina, A. M., Ghosh, C. M., & Morland, L. (1998). The nuts and bolts of behavioral observation of marital and family interaction. Clinical *Child and Family Psychology Review*, 1(4), 195-213.

McEwen, B. S. (2006). Protective and damaging effects of stress mediators: central role of the brain. Dialogues *in clinical neuroscience*, 8(4), 367.

McHale, S. M. (2005). Siblings' differential treatment in Mexican american families. *Journal of Marriage and Family, 67*(5), 1259-1274.

Milne, L. (2009). Long term developmental impact of social withdrawal in infants. *Infant Behavior & Development, 32*(2), 159.

Montgomery, G. G. T. (1992). Acculturation, stressors, and somatization patterns among students from extreme south texas. *Hispanic Journal of Behavioral Sciences, 14*(4), 434-454.

Moore, G. A., & Calkins, S. D. (2004). Infants' vagal regulation in the still-face paradigm is related to dyadic coordination of mother-infant interaction. *Developmental Psychology*, 40(6), 1068-1080.

Moshe, M. & Feldman, R. (2006). Maternal and infant heart rhythms and mother-infant synchrony. A paper presented at the biennial conference of the World Association for Infant and Mental Health. Paris, France.

Munck, Guyre, & Holbrook (1984). Physiological Functions of Glucocorticoids in Stress and Their Relation to Pharmacological Actions. Endocrine *reviews*, 5(1), 25-44.

Murray, L. L. (1997). Effects of postnatal depression on infant development. *Archives of Disease in Childhood, 77*(2), 99-101.

Nachmias, M., Gunnar, M., Mangelsdorf, S., Parritz, R. H., & Buss, K. (1996). Behavioral inhibition and stress reactivity: The moderating role of attachment security. Child *development*, 67(2), 508-522.

Najarian, L. M., & Fairbanks, L. A. (1996). Basal cortisol, dexamethasone suppression of cortisol, and MHPG in adolescents after the 1988 earthquake in Armenia. Am *J Psychiatry*, 153, 929-934.

Neu, M., Laudenslager, M. L., & Robinson, J. (2009). Coregulation in salivary cortisol during maternal holding of premature infants. Biological *research for nursing*, 10(3), 226-240.

Page, R. R. L. (2004). Positive pregnancy outcomes in Mexican immigrants: What can we learn? *Journal of Obstetric, Gynecologic, and Neonatal Nursing*, *33*(6), 783-790.

Papousek, M. (2007). Communication in early infancy: An arena of intersubjective learning. *Infant Behavior & Development, 30*(2), 258.

Parke, R. D. (2004). Economic stress, parenting, and child adjustment in Mexican american and european american families. *Child Development,* , 1632.

Patterson, G. R. (1982). A social learning approach: Coercive family process (Vol. 3). Eugene*, OR: Castalia*.

Pollak, S. D. (2008). Mechanisms Linking Early Experience and the Emergence of Emotions Illustrations From the Study of Maltreated Children. Current *Directions in Psychological Science*, 17(6), 370-375.

Porges, S. W. (2003). The Polyvagal Theory: phylogenetic contributions to social behavior. Physiology *& Behavior*, 79(3), 503-513.

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology*, *28*(7), 916-931.

Reck, C. C. (2004). Interactive regulation of affect in postpartum depressed mothers and their infants: An overview. *Psychopathology, 37*(6), 272-280.

Repetti, R. L., Wang, S. W., & Sears, M. S. (2012). Using Direct Observational Methods to Study the Real Lives of Families: Advantages, Complexities, and Conceptual and Practical Considerations. In *Grzywacz, JG & Demerouti, E. New Frontiers in Work and Family Research. New York, NY: Psychology Press and Routledge*.

Reyna, B. B. A. (2009). Mother-infant synchrony. *Journal of Obstetric, Gynecologic, and Neonatal Nursing, 38*(4), 470-477.

Roberts, R. E., Attkisson, C. C., & Rosenblatt, A. (1998). Prevalence of psychopathology among children and adolescents. *American Journal of Psychiatry, 155,* 715-725.

Rosenblatt, J. S. (1965). The basis of synchrony in the behavioral interaction between the mother and her offspring in the laboratory rat. In B. M. Foss Editor (Ed.), *Determinants of infant behaviour III* (pp. 3-41). London: Methuen.

Sameroff, A. J. (1983). Familial risk and child competence. *Child Development,* , 1254.

Sanchez, M., Ladd, C. O., & Plotsky, P. M. (2001). Early adverse experience as a developmental risk factor for later psychopathology: evidence from rodent and primate models. Development *and psychopathology*, 13(03), 419-449.

Schmidt, L. A., Fox, N. A., Schulkin, J., & Gold, P. W. (1999). Behavioral and psychophysiological correlates of self-presentation in temperamentally shy children. *Developmental Psychobiology, 35*(2), 119-135.

Schneirla, T. T. C. (1946). Problems in the bio-psychology of social organization. *Journal of Abnormal and Social Psychology, 41*(4), 385-402.

Sethre-Hofstad, L., Stansbury, K., & Rice, M. A. (2002). Attunement of maternal and child adrenocortical response to child challenge.*Psychoneuroendocrinology*, 27(6), 731-747.

Shaw, D. S., Bell, R. Q., & Gilliom, M. (2000). A truly early starter model of antisocial behavior revisited. Clinical *Child and Family Psychology Review*, 3(3), 155-172.

Shirtcliff, E. A., Granger, D. A., Booth, A., & Johnson, D. (2005). Low salivary cortisol levels and externalizing behavior problems in youth. *Development and Psychopathology*, *17*(01), 167-184.

Skowron, E. A., Cipriano-Essel, E., Gatzke-Kopp, L. M., Teti, D. M., & Ammerman, R. T. (2013). Early adversity, RSA, and inhibitory control: Evidence of children's neurobiological sensitivity to social context. *Developmental Psychobiology.*

Spangler, G., & Grossmann, K. E. (1993). Biobehavioral organization in securely and insecurely attached infants. Child *development*, 64(5), 1439-1450.

Spangler, G., Schieche, M., Ilg, U., Maier, U., & Ackermann, C. (1994). Maternal sensitivity as an external organizer for biobehavioral regulation in infancy. Developmental *psychobiology*, 27(7), 425-437.

Stern, D. N. (1985). *The interpersonal world of infant: A view from psycho-analysis and developmental psychology*. New York, NY: Basic Books.

Swain, J. E., Lorberbaum, J. P., Kose, S., & Strathearn, L. (2007). Brain basis of early parent-infant interactions: Psychology, physiology, and in vivo functional neuroimaging studies. *Journal of Child Psychology and Psychiatry, 48*(3-4), 262-287. doi:10.1111/j.1469-7610.2007.01731.x

Tabachnik, B. and Linda S.F.. *Using Multivariate Statistics*, (Second Ed.), Harper & Row, NewYork, 1989.

Thelen, E. (1991). Hidden skills: A dynamic systems analysis of treadmill stepping during the first year. *Monographs of the Society for Research in Child Development,*

Thelen, E., & Smith, L. B. (2006). Dynamic systems theories. Handbook of child psychology.

Trevarthen, C., & Aitken, K. J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. Journal *of Child Psychology and Psychiatry*, 42(1), 3-48.

Tronick, E. Z. (1989). Infant-mother face-to-face interaction: Age and gender differences in coordination and the occurrence of miscoordination. *Child Development* , 85.

Tronick, E. Z., & Weinberg, M. K. (1997). Depressed mothers and infants: Failure to form dyadic states of consciousness. In L. Murray, & P. J. Cooper (Eds.), *Postpartum depression and child development.* (pp. 54-81) New York, NY, US: Guilford Press.

U.S. Census Bureau. (2004). *The Hispanic population in the United States: 2004 detailed tables.* Umaña-Taylor, A. J., & Updegraff, K. A. (in press). Latino families in the United States. In G. W. Peterson, & K. R. Bush (Eds.), *Handbook of marriage and the family* (3rd ed.).

U.S. Census Bureau. (2003). *The Hispanic population in the United States: March 2002.* Washington, D.C.: U.S. Department of Commerce Economics and Statistics Administration.

Umaña-Taylor, A. A. J. (2001). Methodological implications of grouping Latino adolescents into one collective ethnic group. *Hispanic Journal of Behavioral Sciences, 23*(4), 347-362.

Umaña-Taylor, A. A. J. (2009). The central role of familial ethnic socialization in Latino adolescents' cultural orientation. *Journal of Marriage and Family, 71*(1), 46-60.

Umaña-Taylor, A. J. (2004). Immigrant mothers' experiences with ethnic socialization of adolescents growing up in the US: An examination of Colombian, Guatemalan, Mexican, and Puerto Rican mothers. *Sociological Focus (Kent, Ohio), 37,* 329.

van Bakel, H. J., & Riksen-Walraven, J. M. (2008). Adrenocortical and behavioral attunement in parents with 1-year-old infants. Developmental *Psychobiology*, 50(2), 196-201.

Vigil, D. D. C. (2004). Interaction styles in minority caregivers: Implications for intervention. *Communication Disorders Quarterly, 25*(3), 119-126.

von Bertalanffy, L. (1968). *General system theory; foundations, development, applications*. New York, NY: G. Braziller.

Weinberg, M. K., & Tronick, E. Z. (1998). Emotional characteristics of infants associated with maternal depression and anxiety. Pediatrics, 102(Supplement E1), 1298-1304.

West, S.G., Finch, J.F., & Curran, P.J. (1995). Structural equation models with non-normal variables: Problems and remedies. In R. Hoyle (Ed.), *Structural Equation Modeling: Concepts, Issues and Applications*, (pp. 56-75). Newbury Park, CA: Sage.

Wolff, P. H. (1967). The role of biological rhythms in early psychological development. *Bulletin of the Menninger Clinic*, 31, 197-218.

Yehuda, R., Halligan, S. L., & Grossman, R. (2001). Childhood trauma and risk for PTSD: relationship to intergenerational effects of trauma, parental PTSD, and cortisol excretion. Development *and Psychopathology*, 13(3), 733-753.

Zero to Three. (1994). *Zero to three, national center for clinical infant programs*. Arlington, VA: Zero to Three, National Center for Clinical Infant Programs.

Table 1.
Participant Characteristics.

	N / %	Range	Mean	Std. Dev
Age	322	18 - 42	27.80	6.47
Years education	323	0 - 18	10.14	3.20
Years in US (if immigrant)	279	0 - 32	11.88	5.97
Annual household income	315	2,500 - 97,500	15849	12824.34
Num. other children	321	0 - 9	1.98	1.67
APGAR 1 min after birth	298	1 - 9	8.30	1.13
APGAR 5 min after birth	298	5 - 10	8.92	0.43
Baby's birth weight in grams	296	612 - 4935	3382.67	487.25
Baby gestational age (weeks)	323	26 - 42	39.32	1.41
Preferred language (% Spanish)	80.8%			
Immigrant status (% immigrant)	86.4%			
Romantic partner (% with partner)	77.4%			
Marital status (% married)	31.9%			
Baby's gender (% boy)	45.8%			

Table 2.

Descriptive Statistics for Cortisol Covariates

	Frequency	Percent
Breastfeeding status (breastfeeding)	51	15.80%
Birth Control (taking birth control)	28	8.70%
Baby eating (within hour)	126	39.00%
Mom eating (within hour)	39	12.00%
Mom caffeine (within hour)	20	6.10%
Mom caffeine (high usage)	1	0.30%
Mom exercise (within hour)	6	1.80%
Mom pregnancy (currently pregnant)	1	0.30%

Table 3.
Descriptive Statistics for Key Study Variables

	N	Range	Mean	Std. Deviation	Skewness	Kurtosis
Global Synchrony Variables- T1						
CIB Reciprocity	168	1 - 5	3.32	0.92	-0.25	-0.38
CIB Adapt-Reg.	169	1 - 5	3.60	0.82	-0.40	0.04
CIB Fluency	169	1 - 5	3.67	0.87	-0.62	0.25
CIB Child-Led	168	1 - 5	3.24	0.87	-0.08	-0.76
Micro (SSG) Synchrony Variables- T1						
NNE Flexibility	144	0 - .90	0.48	0.23	-0.53	-0.58
NNE Duration	144	0 - 300	39.35	27.76	1.41	2.92
NNE Return Time	123	1 – 10.	6.17	2.21	-0.02	-0.75
Overall Flexibility	154	.1 - .90	0.60	0.17	-0.81	0.37
Predictability	154	.7 – 2.5	1.75	0.39	-0.46	-0.26
Physiological Attunement (Cortisol) Variables- T1						
Cort Mom P1	180	.02 - .45	0.13	0.08	1.30	1.42
Cort Mom P2	179	.01 - .65	0.11	0.08	2.71	14.00
Cort Mom P3	176	.01 - .32	0.10	0.06	1.29	1.56
Cort Mom P4	178	.01 - .38	0.09	0.06	1.93	5.36
Cort Baby P1	171	.03 - 3.29	0.33	0.40	3.72	19.40
Cort Baby P2	171	.03 - 2.01	0.29	0.33	2.68	7.61
Cort Baby P3	139	.04 - 1.93	0.24	0.28	3.58	15.94
Cort Baby P4	160	.03 - 2.79	0.24	0.32	4.83	30.53
AUCg Mother	174	.05 - 2.06	.78	.28	.36	2.01
AUCg Baby	116	.48 – 1.75	1.07	.26	.27	.036
Child SE Problems- T2						
BITSEA Ext Probs	188	0 - 12	2.62	2.91	1.44	0.86
BITSEA Int Probs^	188	0 - 11	1.70	1.56	2.23	9.18
BITSEA Dysreg Probs	188	0 - 10	2.45	2.00	0.92	0.73

Note. Full sample n = 323. T1 = 12 weeks postpartum. T2 = 12 months postpartum. SSG = State space grid. Nonneg = Nonnegative. CIB = Coding Interactive Behavior global coding system. Cort = Cortisol value (LN transformed). AUCg = area under the curve with respect to ground (log transformed – base 10). Ext = Externalizing; Int = Internalizing; Dysreg = Dysregulation. ^BITSEA Internalizing was transformed by taking the square root to adjust for nonnormality in subsequent analyses.

Table 4.
Correlations of Cortisol Covariates with Cortisol Samples

	Time of Day (min)	Breast-feed	Mom Cov Flag	Med Flag	Gender (1= girl)	APGAR (1 min)	APGAR (5 min)
Mom Cort P1	-.573**	.065	-.011	.007	-.017	-.066	.077
Mom Cort P2	-.571**	.079	-.050	.004	-.021	.020	.116
Mom Cort P3	-.560**	.088	-.018	-.068	-.001	-.004	.072
Mom Cort P4	-.537**	.029	-.019	-.022	-.062	.015	.088
Baby Cort P1	-.234**	.069	-.078	.075	.106	.053	-.015
Baby Cort P2	-.178*	-.081	-.030	-.042	.060	.056	-.022
Baby Cort P3	-.115	.033	-.046	-.120	.073	.039	-.078
Baby Cort P4	-.112	.036	.069	-.153	.021	.021	-.092
AUCg Mom	-.583**	.057	-.058	.024	-.018	-.012	.091
AUCg Baby	-.112	-.075	-.006	.038	.135	.007	-.104

* $p < .05$, ** $p < .01$
Note. Cort = Salivary cortisol (natural log-transformed). AUCg = Area under the curve with respect to ground. P1 = pre-task; P2 = 0 min post-task; P3 = 20 min post-task; P4 = 40 min post-task. Mom Cov Flag = binary flag for possible covariates (recent eating, caffeine, exercise). Med Flag = binary flag for possibly influential medications.

Table 5.
Inter-Correlations of Key Study Variables

		1	2	3	4	5	6	7	8	9	10
1	CIB Reciprocity	--	.851**	.833**	.682**	.363**	.105	-.431**	.248**	.200*	-.013
2	CIB Adapt-Reg.	--	--	.756**	.777**	.332**	.047	-.359**	.220*	.200*	-.053
3	CIB Fluency	--	--	--	.638**	.288**	-.014	-.295**	.248**	.207*	-.004
4	CIB Child-Led	--	--	--	--	.260**	.103	-.346**	.103	.049	-.062
5	NNE Flexibility	--	--	--	--	--	-.198*	-.252**	.563**	.456**	-.100
6	NNE Duration	--	--	--	--	--	--	-.438**	-.313**	-.485**	.057
7	NNE Return Time	--	--	--	--	--	--	--	-.050	-.039	-.020
8	Overall Flexibility	--	--	--	--	--	--	--	--	.697**	.058
9	Predictability	--	--	--	--	--	--	--	--	--	.133
10	Cort Mom P1	--	--	--	--	--	--	--	--	--	--
11	Cort Mom P2	--	--	--	--	--	--	--	--	--	--
12	Cort Mom P3	--	--	--	--	--	--	--	--	--	--
13	Cort Mom P4	--	--	--	--	--	--	--	--	--	--
14	Cort Baby P1	--	--	--	--	--	--	--	--	--	--
15	Cort Baby P2	--	--	--	--	--	--	--	--	--	--
16	Cort Baby P3	--	--	--	--	--	--	--	--	--	--
17	Cort Baby P4	--	--	--	--	--	--	--	--	--	--
18	Ext Probs	--	--	--	--	--	--	--	--	--	--
19	Int Probs	--	--	--	--	--	--	--	--	--	--
20	Dys Probs	--	--	--	--	--	--	--	--	--	--

		11	12	13	14	15	16	17	18	19	20
1	CIB Reciprocity	-.019	-.019	-.048	-.009	-.192*	-.259**	-.110	.078	-.009	-.007
2	CIB Adapt-Reg.	-.057	-.020	-.052	-.033	-.161	-.209*	-.113	-.009	.009	.041
3	CIB Fluency	.007	.007	-.014	-.055	-.237**	-.317**	-.122	.100	.045	.118
4	CIB Child-Led	-.052	-.042	-.052	-.058	-.160	-.199*	-.060	.003	-.027	.067
5	NNE Flexibility	-.055	-.067	-.100	-.021	-.130	-.318**	-.047	-.018	-.117	-.080
6	NNE Duration	.047	.062	.003	-.134	-.210*	-.124	-.123	-.200	-.142	.040
7	NNE Return Time	-.023	.010	.030	.078	.187*	.184	.119	.007	.032	-.050
8	Overall Flexibility	.064	.065	.090	.019	-.041	-.078	-.017	.226*	.169	.211
9	Predictability	.135	.097	.092	.189*	.082	.013	.085	.318**	.011	.104
10	Cort Mom P1	.914**	.856**	.746**	.299**	.146	.163	.055	.129	.038	-.016
11	Cort Mom P2	--	.931**	.819**	.286**	.196*	.154	.057	.142	.146	.152
12	Cort Mom P3	--	--	.904**	.289**	.196*	.182*	.110	.090	.038	.027
13	Cort Mom P4	--	--	--	.304**	.199**	.180*	.084	.044	.009	.023
14	Cort Baby P1	--	--	--	--	.645**	.388**	.286**	-.134	.061	-.085
15	Cort Baby P2	--	--	--	--	--	.642**	.440**	-.147	-.112	-.200
16	Cort Baby P3	--	--	--	--	--	--	.732**	.158	-.082	-.107
17	Cort Baby P4	--	--	--	--	--	--	--	.167	-.026	-.137
18	Ext Probs	--	--	--	--	--	--	--	--	.283**	.259**
19	Int Probs	--	--	--	--	--	--	--	--	--	.460**
20	Dys Probs	--	--	--	--	--	--	--	--	--	--

Note. T1 = Time 1 (prenatal). Dep = Depressive Symptoms. Marital Status was coded 0 = single, 1 = married or living with partner. T2 = Time 2 (12 weeks). CIB = Coding Interactive Behavior (global coding). NNE = Nonnegative engaged region within the state-space grid. Cort = Salivary Cortisol. Ext = Externalizing. Int = Internalizing. Dys = Dysregulation. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6.
Measurement model for global synchrony latent factor (CIB)

Variables	*B*	*S.E. B*	β	R^2	*SE* R^2
Reciprocity	0.94***	0.03	1.00	.89***	0.05
Fluency	0.88***	0.03	0.89	.78***	0.05
Child-Led	0.72***	0.04	0.72	.52***	0.06

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 7.
Measurement model for micro synchrony latent factor (SSG)

Variables	*B*	*S.E. B*	β	R^2	*SE* R^2
NNE Flexibility	0.62***	0.07	1.00	0.38***	0.08
NNE Mean Time	-0.48***	0.08	-94.79	0.23**	0.08
Overall Flexibility	0.84***	0.05	1.04	0.70***	0.09
Predictability	0.84***	0.05	2.31	0.71***	0.09

Note. † $p < .10$. *$p < .05$. ** $p \leq .01$, *** $p \leq .001$.

Table 8.
Measurement model for mother (MOMCORT) and infant trait cortisol (INFCORT) latent factors

Variables	*B*	*S.E. B*	β	R^2	*SE* R^2
Factor Loadings for MOMCORT					
Cort Mom P1	.90***	0.02	1.00	.80***	0.04
Cort Mom P2	.96***	0.01	1.04	.92***	0.02
Cort Mom P3	.98***	0.01	1.04	.96***	0.02
Cort Mom P4	.90***	0.02	0.97	.81***	0.03
Factor Loadings for INFCORT					
Cort Baby P1	.68***	0.06	1.00	.47***	0.08
Cort Baby P2	.88***	0.05	1.23	.77***	0.09
Cort Baby P3	.80***	0.06	1.04	.63***	0.10
Cort Baby P4	.60***	0.08	0.78	.35***	0.09

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 9.
Measurement model for child SE problems latent factor (BITSEA)

Variables	*B*	*S.E. B*	β	R^2	*SE* R^2
Externalizing Problems	.41***	0.09	1.00	.17*	0.08
Internalizing Problems	.58***	0.11	0.34	.40**	0.14
Dysregulation Problems	.63***	0.11	1.05	.34**	0.12

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 10.

Path model between global (CIB) synchrony at T1 and SE problems (BITSEA) at T2 using latent factors

Variables	*B*	*S.E. B*	β
Factor Loadings for CIB			
Reciprocity	.94***	.03	1.00
Fluency	.88***	.03	.89
Child-Led	.72***	.04	.72
Factor Loadings for BITSEA			
Externalizing Problems	.41***	.09	1.00
Internalizing Problems	.58***	.09	.34
Dysregulation Problems	.61***	.10	1.07
Predictor Variables for BITSEA			
Prenatal Maternal Depression	.36***	.09	.07
Mother Age	.08	.10	.02
Mother Education	-.01	.10	.00
CIB	.07	.14	.10
R^2	0.14*	.07	

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 11.
Path model between micro (SSG) synchrony at T1 and SE problems (BITSEA) at T2 using latent factors

Variables	*B*	*S.E. B*	β
Factor Loadings for SSG			
NNE Flexibility	.62***	.07	1.00
NNE Mean Time	-.47***	.08	-93.38
Overall Flexibility	.84***	.05	1.05
Predictability	.84***	.06	2.30
Factor Loadings for BITSEA			
Externalizing Problems	.42***	.09	1.00
Internalizing Problems	.57***	.09	.32
Dysregulation Problems	.64***	.09	1.04
Predictor Variables for BITSEA			
Prenatal Maternal Depression	.36***	.09	.08
Mother Age	.05	.10	.01
Mother Education	.01*	.10	.00
SSG	0.27†	.15	-.02
R^2	.21*	.10	

† p < .10. * p < .05. ** $p \leq .01$, *** $p \leq .001$

Table 12.
Path model between MOMCORT and INFCORT at T1 and SE problems (BITSEA) at T2 using latent factors

Variables	*B*	*S.E. B*	β
Factor Loadings for MOMCORT			
Cort Mom P1	.90***	.02	1.00
Cort Mom P2	.96***	.01	1.04
Cort Mom P3	.98***	.01	1.04
Cort Mom P4	.90***	.02	.97
Factor Loadings for INFCORT			
Cort Baby P1	.69***	.05	1.00
Cort Baby P2	.89***	.05	1.24
Cort Baby P3	.79***	.06	1.03
Cort Baby P4	.58***	.08	.76
Factor Loadings for BITSEA			
Externalizing Problems	.41***	.09	1.00
Internalizing Problems	.58***	.09	.34
Dysregulation Problems	.64***	.09	1.08
Predictor for Mother Trait Cortisol			
INFCORT	.27***	.08	.29
MOMCORT *R2*	0.08†	.04	
Predictor Variables for BITSEA			
Prenatal Maternal Depression	.36***	.09	.08
Mother Age	.10	.10	.02
Mother Education	-.02	.10	-.01
MOMCORT	.20	.13	-.61
INFCORT	-.28*	.14	.41
R^2	.22*		

† $p < .10$. * $p < .05$. ** $p \le .01$, *** $p \le .001$

Table 13.
Path model for manifest CIB variables and child SE problems

Variables	*B*	*S.E. B*	β
Predictors for Externalizing Problems			
Prenatal Maternal Depression	0.12†	.08	.07
Mother Age	.08	.08	.04
Mother Education	-.09	.08	.08
Reciprocity	.21	.20	.66
Fluency	.10	.20	.32
Child-Led	-.23	.17	-.79
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.23	.07	.03
Mother Age	-.05	.08	-.01
Mother Education	-.06	.07	-.01
Reciprocity	.04	.20	.03
Fluency	.19	.19	.15
Child-Led	-.23	.16	-.18
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.19	.07	.07
Mother Age	.06	.08	.02
Mother Education	.07	.07	.04
Reciprocity	-.31	.20	-.67
Fluency	.25	.20	.58
Child-Led	.16	.18	.36
Externalizing R^2	.08	.06	
Internalizing R^2	.09	.06	
Dysregulation R^2	.09†	.05	

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 14.
Path model for manifest SSG variables and child SE problems

Variables	*B*	*S.E. B*	β
Predictors for Externalizing Problems			
Prenatal Maternal Depression	.09	.08	.05
Mother Age	.10	.08	.05
Mother Education	-.01	.08	-.01
NNE Flexibility	0.26*	.13	-3.27
NNE Duration	-.15	.14	-.02
NNE Return Time	-.14	.13	-.17
Overall Flexibility	.09	.16	1.56
Predictability	0.27†	.15	2.03
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.12	.08	.02
Mother Age	.00	.08	.00
Mother Education	-.02	.08	-.01
NNE Flexibility	-.25†	.14	-.75
NNE Duration	-.34*	.15	-.01
NNE Return Time	-.27†	.14	-.08
Overall Flexibility	.37*	.15	1.46
Predictability	-0.27†	.16	-.49
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.20*	.08	.07
Mother Age	.04	.08	.01
Mother Education	.11	.08	.07
NNE Flexibility	-.26†	.15	-2.25
NNE Duration	.11	.16	.01
NNE Return Time	-.05	.16	-.04
Overall Flexibility	.32†	.17	3.63
Predictability	.12	.17	.62
Externalizing R^2	.15*	.06	
Internalizing R^2	.15*	.07	
Dysregulation R^2	.15*	.07	

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 15.
Path model for MOMCORT and INFCORT at T1 in association to manifest SE problems (BITSEA) at T2

Variables	*B*	*S.E. B*	β
Factor Loadings for MOMCORT			
Cort Mom P1	.90***	.02	1.00
Cort Mom P2	.96***	.01	1.04
Cort Mom P3	.98***	.01	1.04
Cort Mom P4	.90***	.02	.97
Factor Loadings for INFCORT			
Cort Baby P1	.69***	.05	1.00
Cort Baby P2	.89***	.05	1.24
Cort Baby P3	.79***	.06	1.03
Cort Baby P4	.58***	.08	.76
Predictor for Mother Trait Cortisol			
INFCORT	.27***	.08	.29
Mother Cortisol R^2	0.08†	.04	
Predictors for Externalizing Problems			
Prenatal Maternal Depression	.11	.07	.06
Mother Age	.12	.08	.06
Mother Education	-.07	.07	-.06
Mother Trait Cortisol	.13	.10	.66
Infant Trait Cortisol	-.11	.31	-.60
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.23***	.07	.03
Mother Age	-.01	.08	.00
Mother Education	-.05	.07	-.01
Mother Trait Cortisol	.11	.10	.14
Infant Trait Cortisol	-.13	.10	-.76
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.23***	.07	.08
Mother Age	.08	.08	.03
Mother Education	.05	.07	.03
Mother Trait Cortisol	.10	.10	.36
Infant Trait Cortisol	-0.21†	.11	-.76
Externalizing R^2	.06	.04	
Internalizing R^2	0.07†	.04	
Dysregulation R^2	.10†	.05	

† $p < .10$. * $p < .05$. ** $p \leq .01$, *** $p \leq .001$

Table 16.

Follow-up path model for dyadic cortisol AUCg difference in association with SE problems

Variables	*B*	*S.E. B*	β
Predictors for Externalizing Problems			
Prenatal Maternal Depression	.10	.07	.06
Mother Age	.12	.08	.06
Mother Education	-.06	.07	-.05
Mother-Infant Cort AUCg Difference	.04	.12	.45
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.24***	.07	.03
Mother Age	-.01	.08	.00
Mother Education	-.06	.07	-.01
Mother-Infant Cort AUCg Difference	-.17	.11	-.42
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.23***	.07	.09
Mother Age	.08	.08	.02
Mother Education	.05	.08	.03
Mother-Infant Cort AUCg Difference	-.26*	.11	-1.83
Externalizing R^2	.04	.03	
Internalizing R^2	.13†	.07	
Dysregulation R^2	.08†	.05	

† p < .10. * p < .05. ** $p \leq .01$, *** $p \leq .001$

Table 17.
Follow-up path model for manifest CIB and SSG variables, MOMCORT, INFCORT and manifest SE problems

Variables	*B*	*S.E. B*	β
Predictor for Mother Trait Cortisol			
Infant Trait Cortisol	.27***	.08	.29
Mother Cortisol R^2	.07†	.04	
Predictors for Externalizing Problems			
Prenatal Maternal Depression	.11	.09	.06
Mother Age	.08	.09	.04
Mother Education	-.04	.09	-.03
Reciprocity	.20	.23	.63
Fluency	-.02	.20	-.06
Child-Led	-.16	.17	-.53
NNE Flexibility	-.27*	.13	-3.36
NNE Duration	-.18	.14	-.02
NNE Return Time	-.10	.50	-.12
Overall Flexibility	.04	.16	.59
Predictability	.31*	.15	2.34
Mother Trait Cortisol	.11	.10	.54
Infant Trait Cortisol	-.24*	.11	-1.30
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.13	.09	.02
Mother Age	-.03	.09	.00
Mother Education	-.05	.08	-.01
Reciprocity	-.01	.23	-.01
Fluency	.14	.19	.11
Child-Led	-.20	.16	-.16
NNE Flexibility	-.23	.14	-.68
NNE Duration	-.34*	.14	-.01
NNE Return Time	-.25	.15	-.07
Overall Flexibility	.33*	.16	1.32
Predictability	-.23	.16	-.42
Mother Trait Cortisol	.11	.10	.14
Infant Trait Cortisol	-.17	.12	-.22
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.15†	.09	.05
Mother Age	.04	.09	.01
Mother Education	.12	.08	.08
Reciprocity	-.49*	.22	-1.06
Fluency	.25	.19	.57

Child-Led	.23	.16	.52
NNE Flexibility	-.31*	.14	-2.75
NNE Duration	.13	.15	.01
NNE Return Time	-.10	.16	-.09
Overall Flexibility	.39*	.16	4.47
Predictability	.22	.17	1.14
Mother Trait Cortisol	.07	.10	.25
Infant Trait Cortisol	-.22†	.12	-.81
Externalizing R^2	.21**	.09	
Internalizing R^2	.29**	.09	
Dysregulation R^2	.20**	.08	

† $p < .10$. * $p < .05$, ** $p \leq .01$, *** $p \leq .001$

Table 18.
Follow-up path model for manifest CIB, SSG, and AUCg variables in association with SE problems

Variables	*B*	*S.E. B*	β
Predictors for Externalizing Problems			
Prenatal Maternal Depression	.10	.08	.05
Mother Age	.06	.09	.03
Mother Education	-.04	.08	-.04
Reciprocity	.18	.23	.55
Fluency	.07	.21	.22
Child-Led	-.19	.17	-.62
NNE Flexibility	-.26*	.13	-3.26
NNE Duration	-.16	.14	-.02
NNE Return Time	-.12	.14	-.15
Overall Flexibility	.06	.16	1.05
Predictability	.26†	.15	1.97
Mother-Infant Cort AUCg Difference	-.05	.12	-.54
Predictors for Internalizing Problems			
Prenatal Maternal Depression	.13	.09	.02
Mother Age	-.04	.09	.00
Mother Education	-.05	.08	-.01
Reciprocity	.00	.22	.00
Fluency	.11	.19	.09
Child-Led	-.20	.16	-.16
NNE Flexibility	-.25†	.14	-.75
NNE Duration	-.38*	.15	-.01
NNE Return Time	-.29†	.15	-.09
Overall Flexibility	.37*	.15	1.48
Predictability	-.26†	.15	-.46
Mother-Infant Cort AUCg Difference	-.27*	.12	-.64
Predictors for Dysregulation Problems			
Prenatal Maternal Depression	.14	.09	.05
Mother Age	.04	.09	.01
Mother Education	.11	.08	.07
Reciprocity	-.51*	.21	-1.11
Fluency	.18	.19	.42
Child-Led	.28†	.15	.64
NNE Flexibility	-.32*	.13	-2.84
NNE Duration	.06	.15	.00
NNE Return Time	-.14	.15	-.12
Overall Flexibility	.44**	.15	5.09

Predictability	.16	.15	.86
Mother-Infant Cort AUCg Difference	-.36**	.12	-2.49
Externalizing R^2	.18*	.07	
Internalizing R^2	.38***	.10	
Dysregulation R^2	.25**	.09	

† $p < .10$, * $p < .05$, ** $p \leq .01$, *** $p \leq .001$

Table 19.
Measurement model for behavioral synchrony ("BEHSYNC") latent factor

Variables	*B*	*S.E. B*	β	R^2	*SE* R^2
Reciprocity	.10***	.02	1.00	0.93	0.04
Fluency	.87***	.03	.85	0.75	0.05
Child-Led	.71***	.04	.70	0.51	0.06
NNE Flexibility	.41***	.08	.11	0.17	0.06
NNE Return Time	-.48***	.08	-1.20	0.24	0.08
Overall Flexibility	.28***	.09	.05	0.08	0.05
Predictability	.23***	.09	.10	0.06	0.04

*** $p < .001$

Table 20.
Path model for BEHSYC latent factor, MOMCORT, and INFCORT associated with BITSEA

Variables	*B*	*S.E. B*	β
Predictor for MOMCORT			
Infant Trait Cortisol	.27***	.08	.29
Mother Cortisol R^2	.08†	.04	
Predictor Variables for BITSEA			
Prenatal Maternal Depression	.37***	.09	.08
Mother Age	.09	.10	.02
Mother Education	-.02	.10	.00
MOMCORT	.20	.13	.41
INFCORT	-.27†	.14	-.59
BEHSYNC	.07	.14	.09
BITSEA R^2	.23*	.10	

† $p < .10$, * $p < .05$, *** $p \leq .001$

Table 21.

Path model for BEHSYC latent factor and cortisol AUCg difference associated with BITSEA

Variables	*B*	*S.E. B*	β
Predictor Variables for BITSEA			
Prenatal Maternal Depression	.37***	.09	.08
Mother Age	.08	.10	.01
Mother Education	-.02	.10	-.01
AUCg Difference	-.29	.16	-1.14
BEHSYNC	.06	.14	.07
BITSEA R^2	.22*	.10	

* p < .05., *** $p \leq .001$

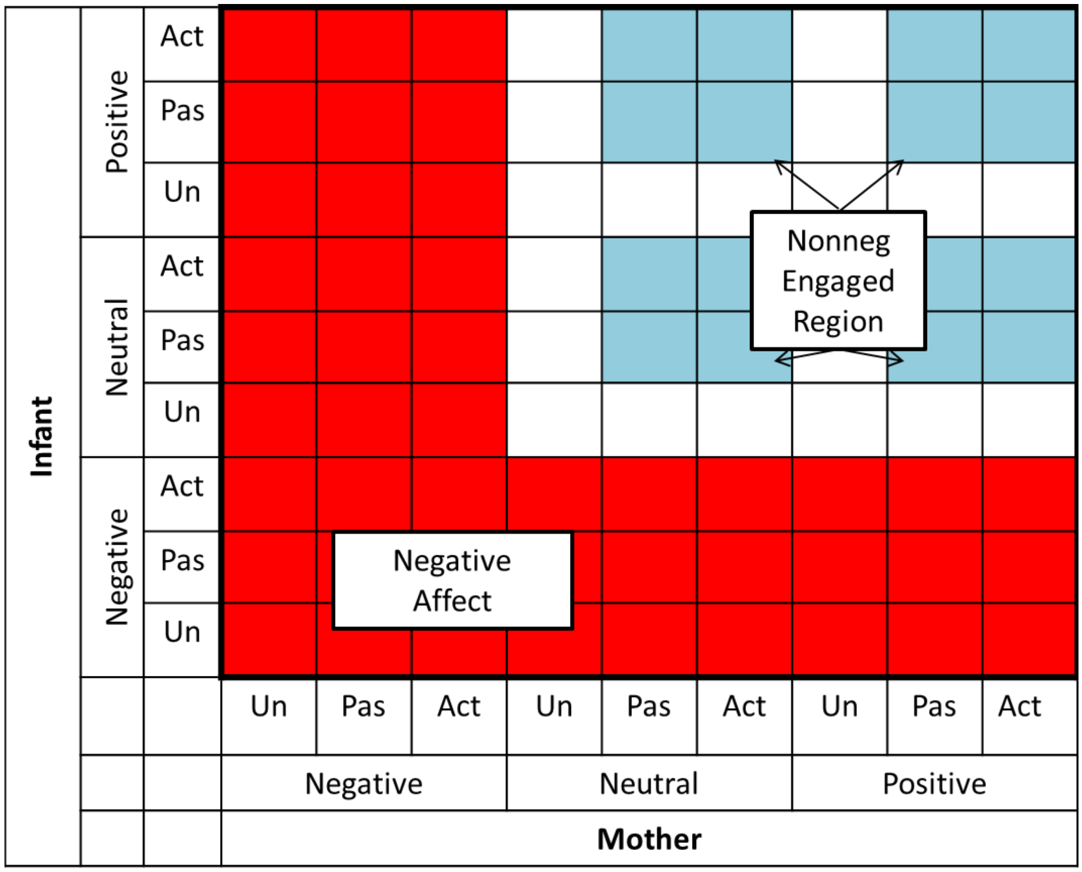

Figure 1. Conceptual State-Space Grid for Engagement and Affect in Mothers and Infants. Nonneg=Nonnegative Affect (either positive or neutral for both members of dyad), Neutral=Neutral Affect, Positive=Positive Affect, Un=Unengaged, Pas=Passive Engaged, Act=Active Engaged.

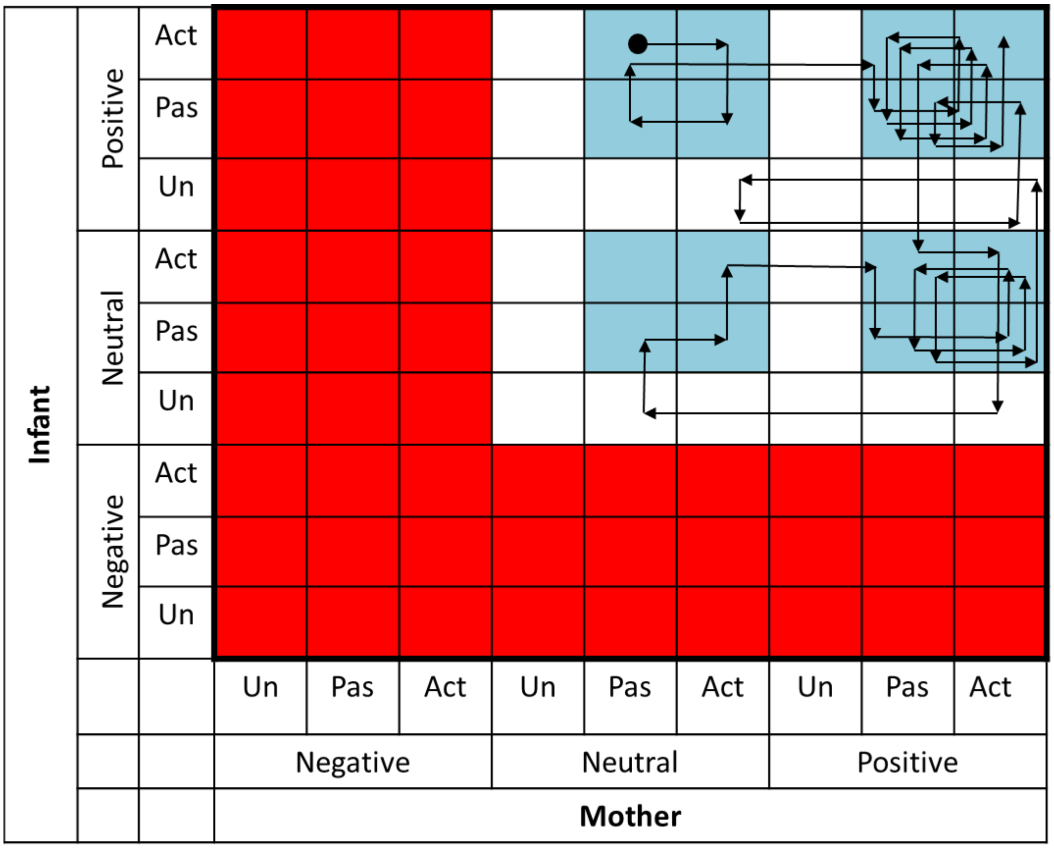

Figure 2. Conceptual representation of high synchrony state-space grid. Negative=Negative Affect, Neutral=Neutral Affect, Positive=Positive Affect, Un=Unengaged, Pas=Passive Engaged, Act=Active Engaged.

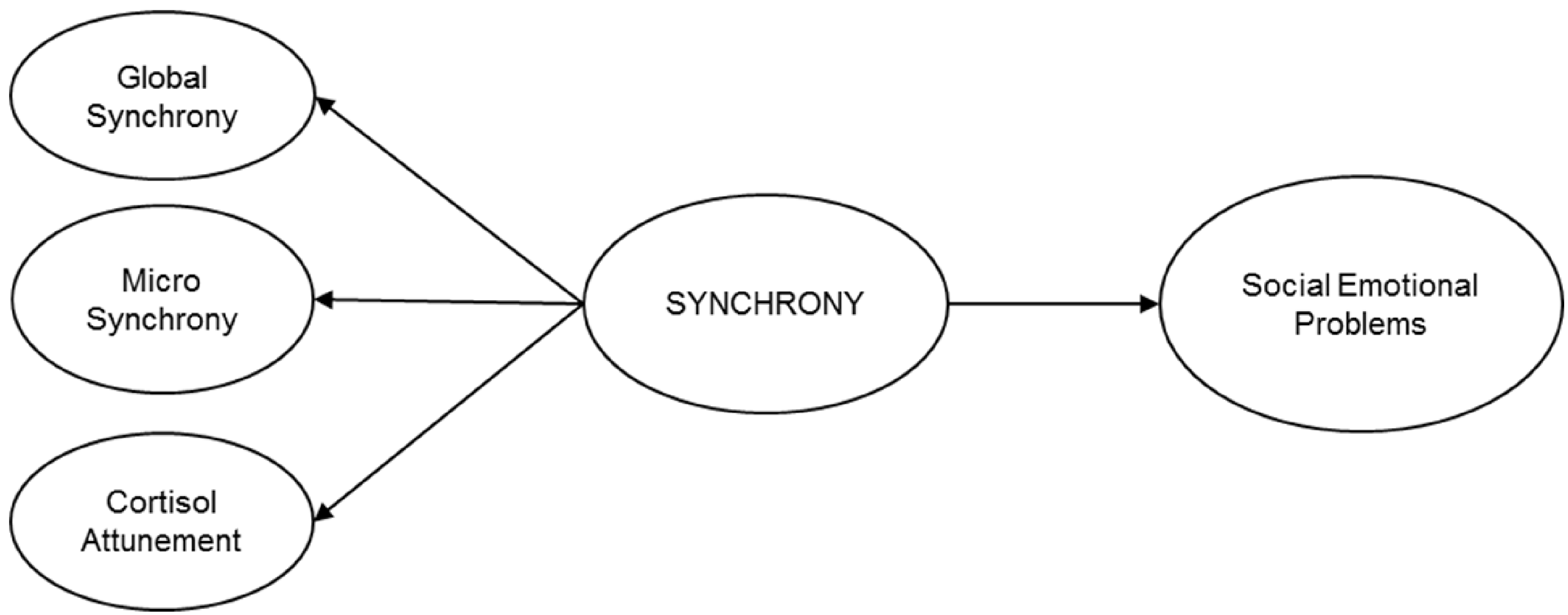

Figure 3. Theoretical prospective model of synchrony and subsequent social emotional problems.

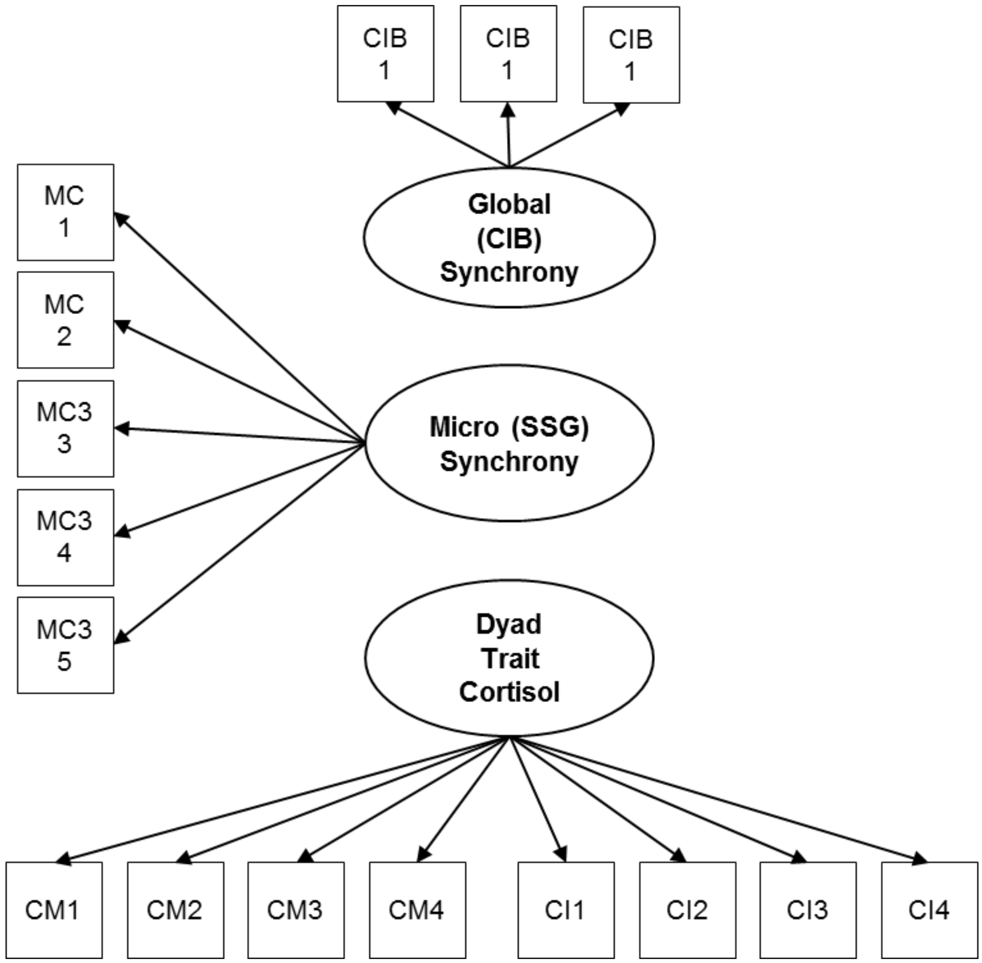

Figure 4. Planned measurement models for synchrony variables. Separate and independent measurement models were estimated for global, micro, and cortisol synchrony. T1=Infant age 12 weeks, T2=Infant age 12 months. CIB1= Reciprocity, CIB2= Fluency, CIB3= Child-Led. MC1= Micro Nonnegative Engaged Flexibility, MC2= Nonnegative Engaged Mean Duration, MC3=Nonnegative Engaged Return Time, MC4 = T1 Micro Overall Flexibility, MC5 = Predictability. CM1-4 = Mother cortisol sample time 1 through 4; CI1-4 = Infant cortisol sample time 1 through 4

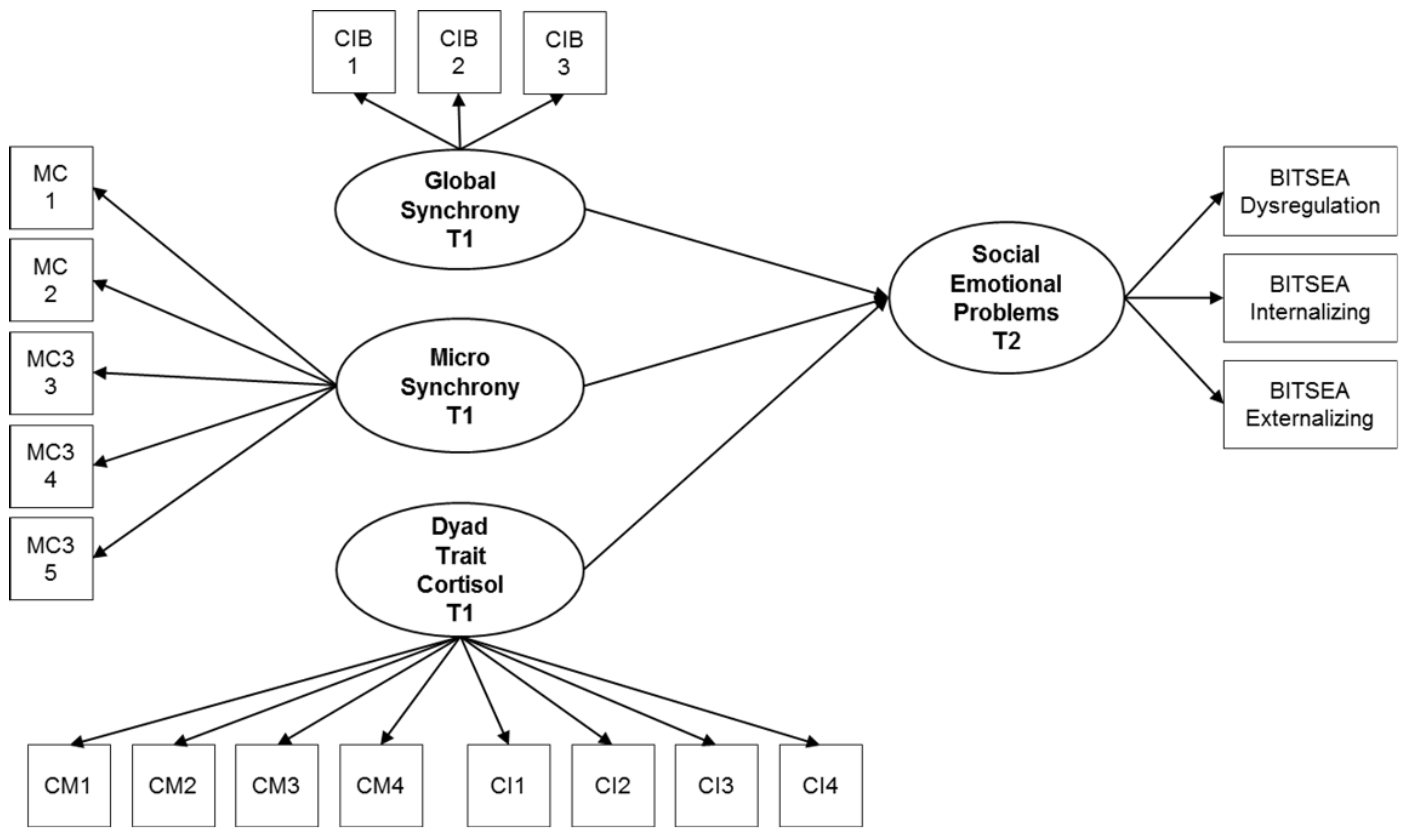

Figure 5. Planned structural equation model for latent constructs of synchrony in association with subsequent child social-emotional (SE) problems. Individual regression analyses for each predictor were estimated prior to testing the combined model. T1=Infant age 12 weeks, T2=Infant age 12 months. CIB1= Reciprocity, CIB2= Fluency, CIB3= Child-Led. MC1= Micro Nonnegative Engaged Flexibility, MC2= Nonnegative Engaged Mean Duration, MC3=Nonnegative Engaged Return Time, MC4 = T1 Micro Overall Flexibility, MC5 = Predictability. CM1-4 = Mother cortisol sample time 1 through 4; CI1-4 = Infant cortisol sample time 1 through 4.

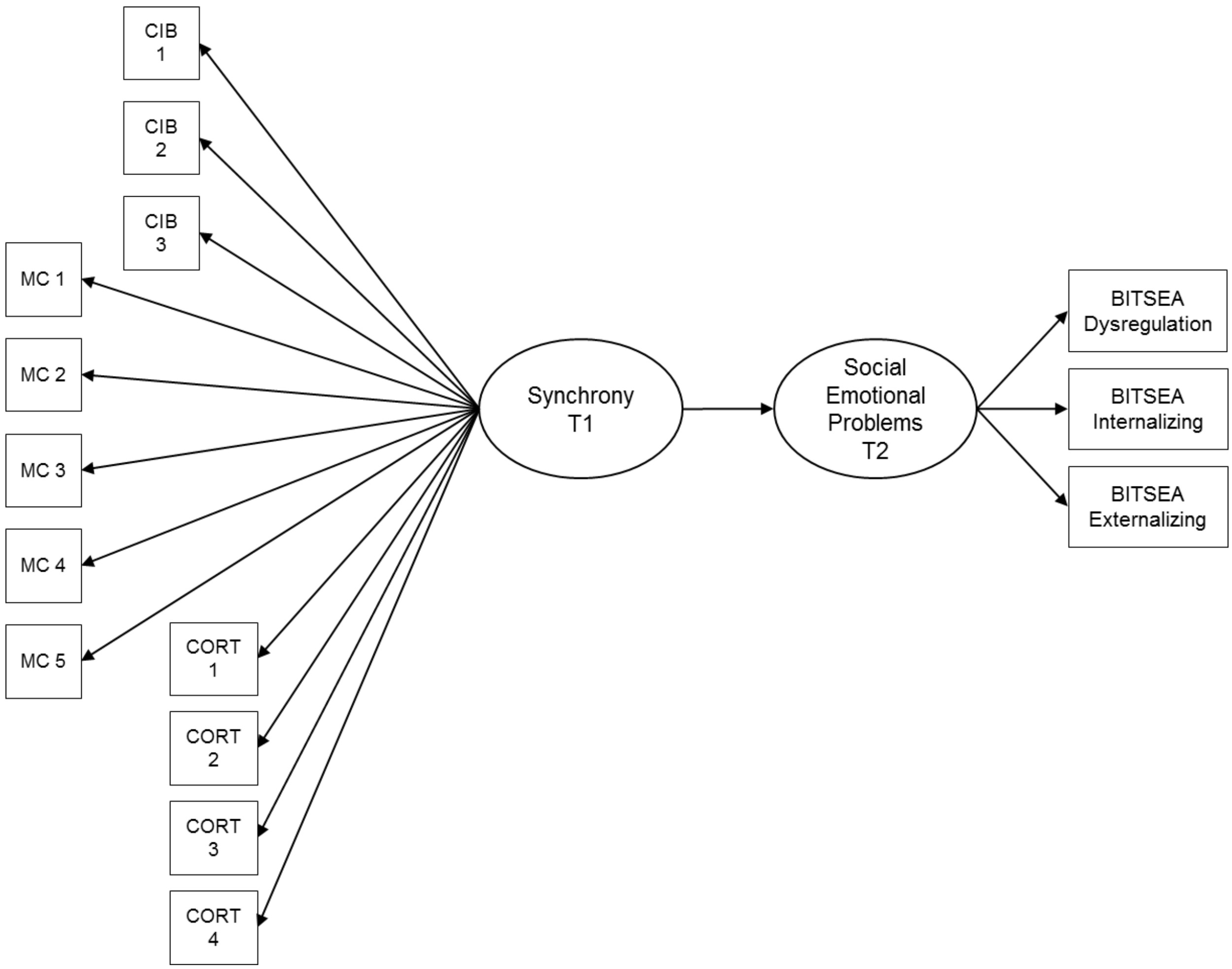

Figure 6. Planned latent factor model as proposed for synchrony in association with social emotional problems. Individual regression analyses for each predictor were estimated prior to testing the combined model. T1=Infant age 12 weeks, T2=Infant age 12 months. CIB1= Reciprocity, CIB2= Fluency, CIB3= Child-Led. MC1= Micro Nonnegative Engaged Flexibility, MC2= Nonnegative Engaged Mean Duration, MC3=Nonnegative Engaged Return Time, MC4 = T1 Micro Overall Flexibility, MC5 = Predictability. CM1-4 = Mother cortisol sample time 1 through 4; CI1-4 = Infant cortisol sample time 1 through 4.

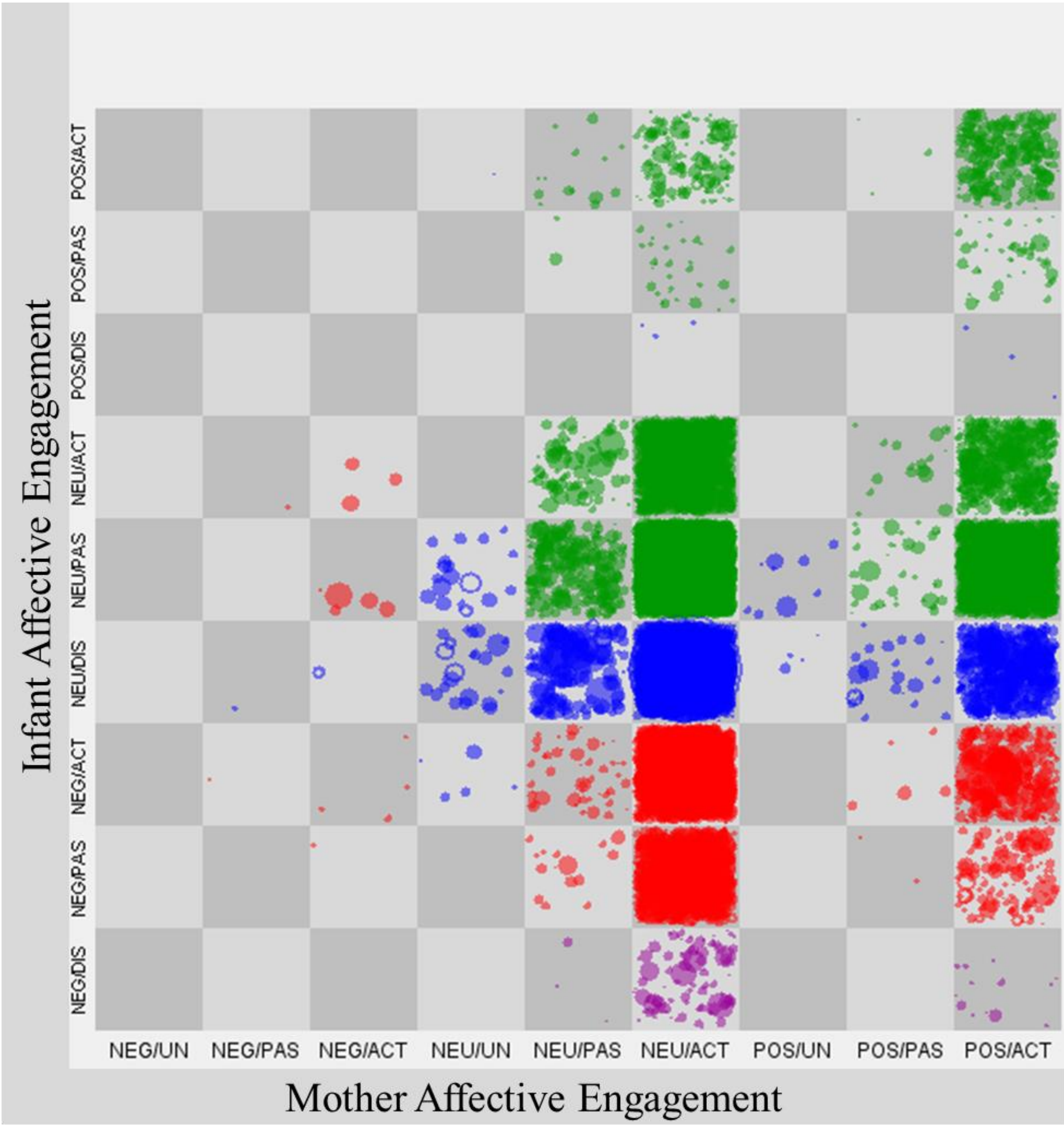

Figure 7

State space grid of affective engagement for full sample. N = 154. Each cell represents a simultaneous dyadic state comprised of the affect and engagement state for both mother (x axis) and infant (y axis). Affective states include NEG = negative, NEU = neutral, POS = positive. Possible engagement states include UN or DIS = unengaged, PAS = passive, or ACT = active. The three regions of interest are indicated as NNE = both partners are in a non-negative engaged state (green), NEG = at least one member of the dyad is in a negative state (red), and UN = at least one member of the dyad is in an unengaged state (blue). Overlap between NEG and UN are indicated in purple.

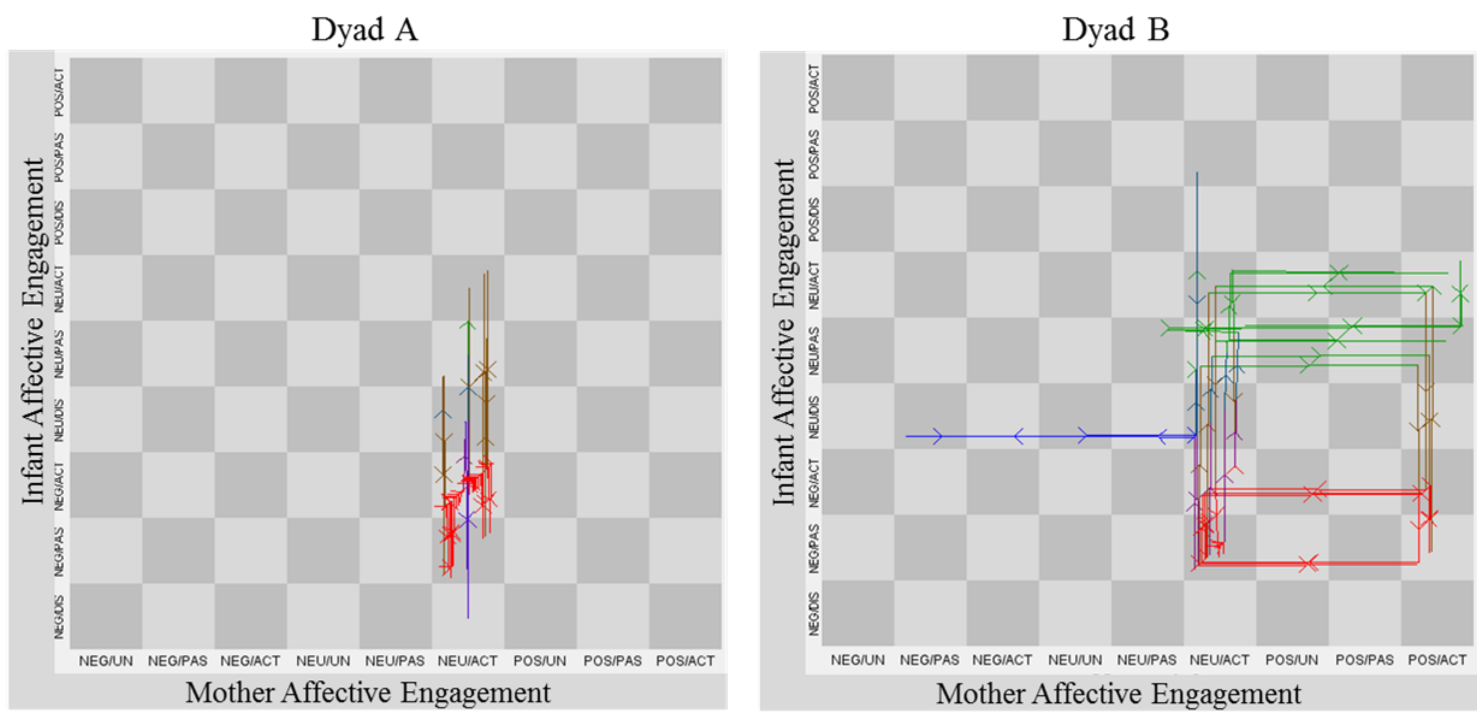

Figure 8A and B.
State space grid of affective engagement for two exemplar dyads, A (left) and B (right). Each cell represents a simultaneous dyadic state comprised of the affect and engagement state for both mother (x axis) and infant (y axis). Affective states include NEG = negative, NEU = neutral, POS = positive. Possible engagement states include UN or DIS = unengaged, PAS = passive, or ACT = active. The three regions of interest are indicated as NNE = both partners are in a non-negative engaged state (green), NEG = at least one member of the dyad is in a negative state (red), and UN = at least one member of the dyad is in an unengaged state (blue). Overlap between NEG and UN are indicated in purple.

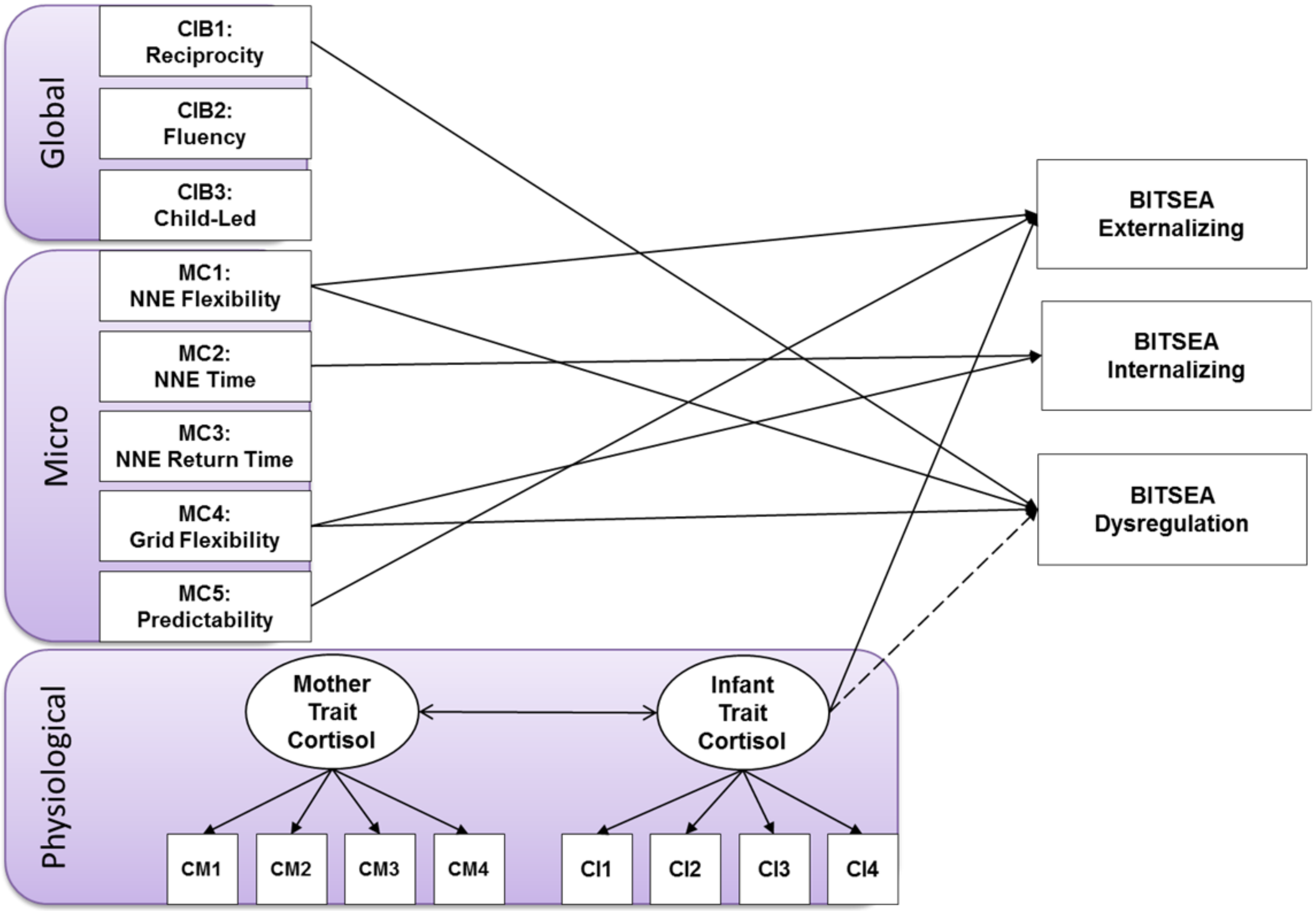

Figure 9

Full path model using manifest variables for behavior and SE problems and mother and infant trait cortisol. Solid arrows indicate significant path coefficient of at least $p < .05$. Dashed arrows indicate marginal path coefficients ($p < .10$). Nonsignificant paths and covariates are not shown. T1=Infant age 12 weeks, T2=Infant age 12 months. NNE = Nonnegative engaged region. CM1-4 = Mother cortisol sample time (P) 1 through 4; CI1-4 = Infant cortisol sample (P) time 1 through 4.

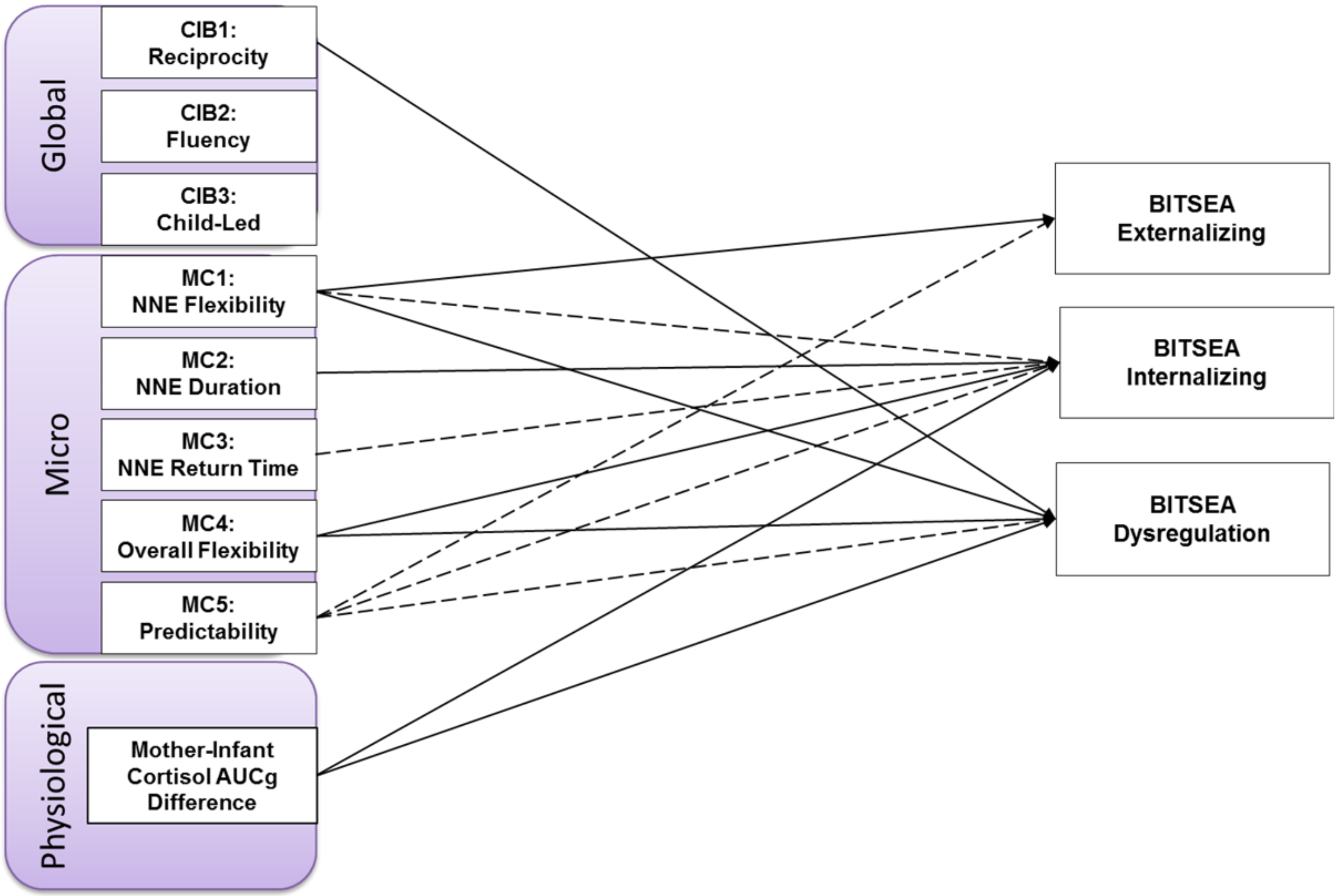

Figure 10
Full manifest path model with mother-infant AUCg cortisol difference score. Solid arrows indicate significant path coefficient of at least $p < .05$. Dashed arrows indicate marginal path coefficients ($p < .10$). Nonsignificant paths and covariates are not shown. T1=Infant age 12 weeks, T2=Infant age 12 months. NNE = Nonnegative engaged region.

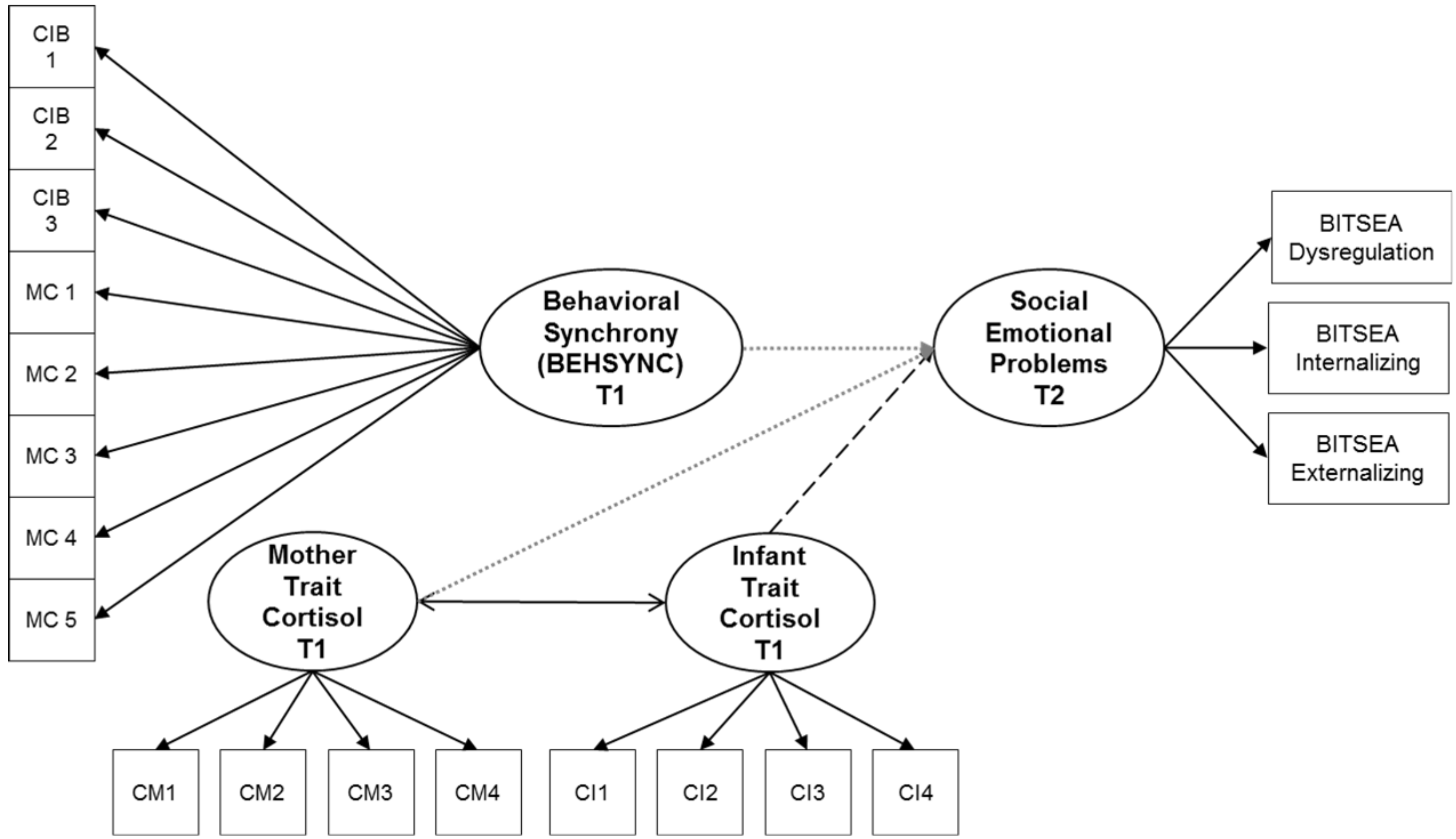

Figure 11.
Full latent path model using BEHSYNC factor for all behavioral measures of synchrony, mother trait cortisol, and infant trait cortisol. T1=Infant age 12 weeks, T2=Infant age 12 months. Solid arrows indicate significant path coefficient of at least $p < .05$. Dotted grey arrows indicate nonsignificant path coefficients. CIB1= Reciprocity, CIB2= Fluency, CIB3= Child-Led. MC1= Micro Nonnegative Engaged Flexibility, MC2= Nonnegative Engaged Mean Duration, MC3=Nonnegative Engaged Return Time, MC4 = T1 Micro Overall Flexibility, MC5 = Predictability. CM1-4 = Mother cortisol sample time 1 through 4; CI1-4 = Infant cortisol sample time 1 through 4.

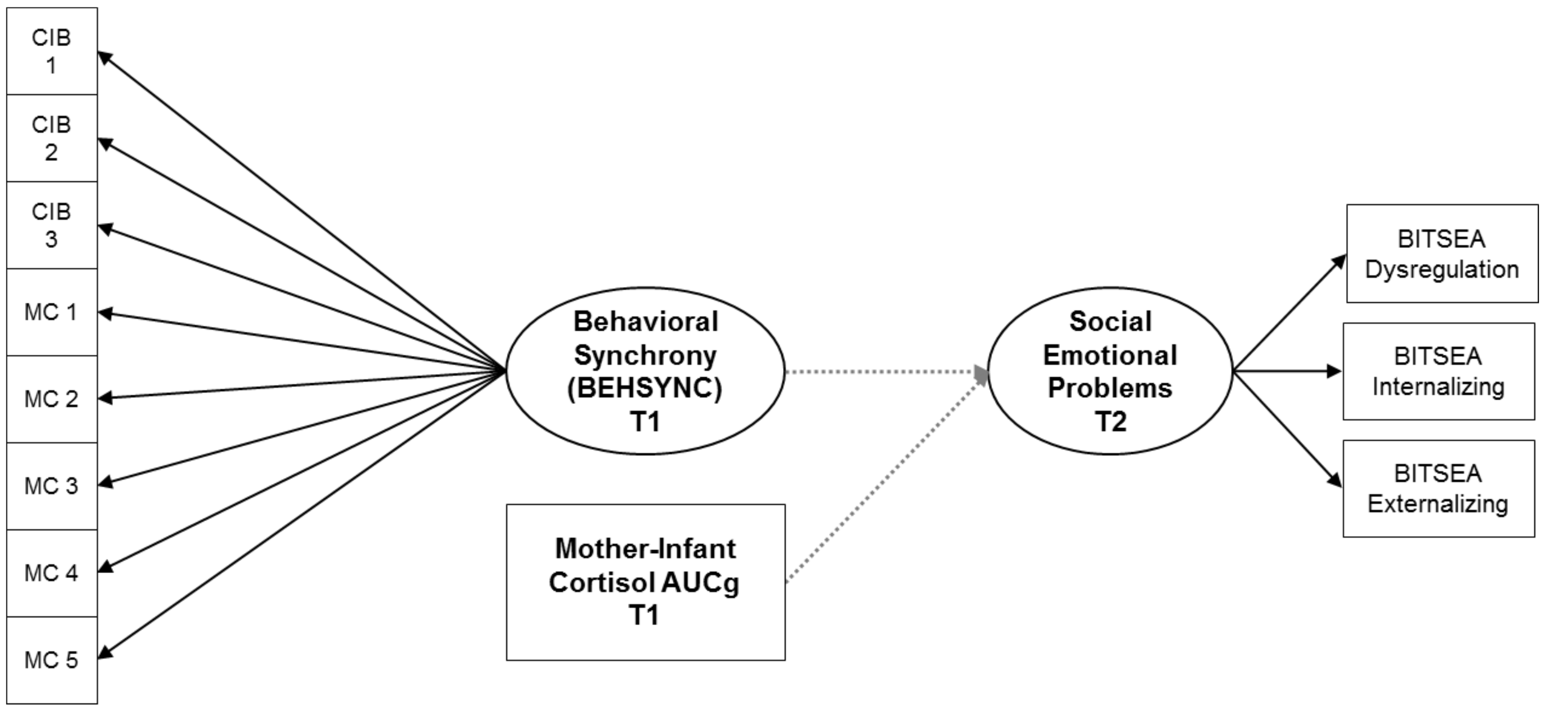

Figure 12.
Full latent path model using BEHSYNC factor for all behavioral measures of synchrony with cortisol AUCg difference. T1=Infant age 12 weeks, T2=Infant age 12 months. Solid arrows indicate significant path coefficient of at least $p < .05$. Dotted grey arrows indicate nonsignificant path coefficients. CIB1= Reciprocity, CIB2= Fluency, CIB3= Child-Led. MC1= Micro Nonnegative Engaged Flexibility, MC2= Nonnegative Engaged Mean Duration, MC3=Nonnegative Engaged Return Time, AUCg Difference = Absolute difference for area under the curve with respect to ground between mothers and infants.