FACIAL AFFECT AND PHYSIOLOGICAL SYNCHRONY DURING PARENT-INFANT INTERACTIONS AND INFLUENCES ON LATER DEVELOPMENTAL OUTCOMES

by

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Dyadic synchrony can be generally defined as the mutual matching or relatedness of behavior or states across time for both members of a dyad during social interactions (Feldman, 2007a). It becomes particularly prominent during parent-infant interactions when the infant is approximately 2-3 months of age and continues to become more complex throughout a child's development (Feldman, 2007a; Harrist & Waugh, 2002). The degree of dyadic synchrony during interactions can be measured through various affective components, such as facial expressions, vocal affect, gaze, body positioning, as well as physiological indices, such as heart rate and/or skin conductance.

It is important to note that, despite its name, many researchers do not consider synchrony to be the simultaneous occurrence of behaviors or states for both members of a dyad. Rather, it is typically viewed as the degree to which the behavior or state of one partner is linked to the other person's temporally, or across time, within the context of an interaction (Cohn & Tronick, 1987; Feldman, 2007a). Indeed, while both are related to social coordination of behavior between partners, researchers distinguish between matching (i.e., the occurrence of the same behavior at the same time) and the degree, or level of synchrony (i.e., changing behavior in relation to social partner; Tronick & Cohn, 1989). For the purposes of the current study, dyadic synchrony was defined as the latter. For instance, a synchronous interaction would be one in which the infant smiles at the mother and, subsequently, the mother smiles back at the infant.

Given the variance in methodology and operationalization of the construct, dyadic synchrony (or similar constructs) during parent-infant interactions has been referred to by several terms, including attunement, mutual engagement, mutual responsiveness, and interaction-contingency (Beebe et al., 2007; Braungart-Rieker, Garwood, Powers, & Notaro, 1998; Harrist & Waugh, 2002; Kochanska, Aksan, Prisco, & Adams, 2008; Ostlund, Measelle, Laurent, Conradt, & Ablow, 2017). Therefore, these terms may be used when reporting previous research findings, in order to stay true to each researcher's conceptualization of synchrony. For further clarification, the broader term *affective* synchrony, which is the behavioral component of interactions (e.g., gaze, vocal affect, facial affect) will be referred to interchangeably as affective synchrony, interactional synchrony, and behavioral synchrony for the purposes of the current paper. These terms are more broad and may encompass synchrony across various modalities, such as gaze, touch, and facial affect synchrony. However, facial affect synchrony refers specifically to the matching of facial affect or facial expressions.

Various factors may influence dyadic synchrony, including parental depressive symptoms, and the quality of the romantic relationship of the parents (e.g., Beebe et al., 2008; Lotzin, Schiborr, Barkmann, Romer, & Ramsauer, 2016; Lundy, 2002). Furthermore, the level of synchrony in parent-infant interactions may predict infant outcomes later in childhood, such as the child's ability to self-regulate (e.g., Feldman, Greenbaum, & Yirmiya, 1999). Thus, the purpose of this study was to examine factors related to parent-infant synchrony when infants were 6-9 months old and outcomes of dyadic synchrony when the child was 3 years old. This study also sought to provide a general description and examine potential predictors and outcomes of father-infant synchrony, which has been understudied relative to mother-infant synchrony.

Dyadic synchrony is often examined through a time series analysis of the amount of time that lapses between the two individuals being asynchronous and then exhibiting contingent behavior once more. An example of this would be the number of seconds between the child shifting gaze and the parent following the child's gaze shift. Focusing on lapses in synchrony entails analyzing the lagged associations between parent and infant behavior to determine the degree to which partners are matching their behavior, as well as the length of the time gap between these changes (Feldman, 2007a). These lagged associations may provide a more appropriate approach to examining dyadic synchrony than non-lagged associations, given that previous research indicates that for the majority of time spent in social interactions, mother-child dyads do not exhibit the same behaviors at the same time (Tronick & Cohn, 1989). Furthermore, the ability of a parent-infant dyad to go from non-matching to matching affective states, which is known as reparation, may be one of the mechanisms through which dyadic synchrony affects the development of self-regulation (DiCorcia & Tronick, 2011; Montirosso, Borgati, Trojan, Zanini, & Tronick, 2010). Because of these factors, the current research utilized a time series design for analyses.

Sensitive Parenting

Conceptually, infant-parent synchrony is closely related to parent responsiveness or sensitivity. Greater sensitivity indicates that a parent is more responsive to infant's cues, which means that the parent quickly senses and adapts to the behavior of an infant during interactions (Parke, 2000). Therefore, infant-parent synchrony during interactions may be an indicator of more sensitive parenting. Indeed, when infants and mothers interacted via live recording in real time, infants focused their gaze on the mother more frequently than when mothers' responses were played back and therefore not contingent to the infant's behavior (Stormark & Braarud, 2004). This suggests that when mothers showed a greater level of responsiveness (i.e., responses were live and thus more contingent on the infants' social cues), infants were more engaged. Just as parent responsiveness, or sensitivity, contributes to the quality of the parent-infant relationship, more synchronous dyadic interactions may be indicative of a better relationship between the parent and infant (Brown, Mangelsdorf, & Neff, 2012).

Both partners play a role in synchrony during an interaction, not only the parent. For instance, synchrony is related to the ability of infants to detect and respond to related occurrences in the environment, particularly social contingencies in which their own behavior is one of the events. However, a review of previous research suggests that infants exhibit the ability of contingency detection, even as neonates, and exhibit mutual affective behavior influences by 9 months (Feldman, 2007b; Tarabulsy, Tessier, & Kappas, 1996). Many developmental psychologists view earlier synchronous interactions as being led by infants, with achievement of synchrony being contingent on parents following the infant's lead. Indeed, a scenario in which the interaction is infant-led is arguably the hallmark of sensitive parenting. Previous research also suggests that interactions are infant-led at 3 to 4 months of age, with more balanced interactions (e.g., each partner "leading" and "following" more equally) developing as the infant approaches 9 months of age (Feldman, 2007a; Feldman et al., 1999; Feldman, Greenbaum, Yirmiya, & Mayes, 1996).

Dyadic synchrony, or behavioral coordination, between infants and their caregivers has been implicated in the development of self-regulation (Feldman, 2007a; Gianino & Tronick, 1988). Better regulatory abilities, such as emotion regulation, are important for a wide variety of later outcomes, including less likelihood of psychopathology, improved social competence, and greater academic achievement (Eisenberg et al., 2001; Graziano, Reavis, Keane, & Calkins, 2007; Penela, Walker, Degnan, Fox, & Henderson, 2015). Given that infants possess only a small range of behaviors to maintain their own levels of arousal, much of their initial regulation is co-regulation utilizing the caregiver. This may be one function of dyadic synchrony, whereby infants and caregivers observe affective cues from one another and react accordingly, as suggested by the proposed mutual regulation model (Gianino & Tronick, 1988). The results of a longitudinal study of 4- and 9-month-olds indicated that more contingent responding by the mother predicted better emotion regulation, or increased positive affect in the Still Face Procedure, which is typically a stressful situation for infants (Lowe et al., 2012). This provides further evidence that more contingent parent-infant interactions play an important role in the development of self-regulation.

Furthermore, the theory of bio-behavioral synchrony posits that the attachment bond between two individuals (e.g., infant and parent) is highly dependent on each person's behaviors, as well as the temporal component of experience (Feldman, 2012). This theory is supported by previous research, the findings of which show that there is a bidirectional relationship between infants' and caregivers' behavior across time (Cohn & Tronick, 1988). In addition, bio-behavioral synchrony theory stresses the importance of studying both physiological and behavioral components of partners' responses during interactions for greater understanding of interactional processes.

Still Face Procedure

The Still Face Procedure or Paradigm (SFP; Tronick, Als, Adamson, Wise, & Brazelton, 1978) provides an optimal set of interactions during which infant-caregiver synchrony can be studied. This is the case because the procedure consists of three separate episodes—a face-to-face episode of free play (FP), a still face (SF) episode, and a reunion (RE) episode, which typically elicit a range of affective responses (e.g., joy, sadness) from both caregiver and infant. Moreover, the nature of the SFP allows temporal examination of the associations between caregiver and infant responses. Within the SFP, the infant is typically placed in a seat facing the caregiver. The caregiver is first asked to engage in naturalistic play with their infant without utilizing any toys. The caregiver is then asked to continue facing and looking directly at their infant while remaining unresponsive and exhibiting a neutral facial expression for the duration of the still face episode. Finally, for the reunion episode, caregivers are instructed to re-engage with their infant in an episode of play, like that of the initial free play episode. Each episode typically lasts either 2 or 3 min, depending on the particular protocol of the researchers.

Previous research has provided extensive information regarding the typical patterns of infant response during the SFP. For instance, during the FP episode, infants expressed primarily joy and low levels of negative affect (Weinberg & Tronick, 1996). However, during the SF episode, research has consistently found that infants displayed a decrease in positive affect, an increase in negative affect, and spent significantly more time looking away from the caregiver (Adamson & Frick, 2003; Chow, Haltigan, & Messinger, 2010). The infants' change of affective response from the FP to the SF, particularly becoming upset at the mother's act of disengaging from them during the SF episode, is called the still face effect (Adamson & Frick, 2003). The still face effect has been found during infants' interactions in the SFP with both mothers and fathers (Braungart-Rieker et al., 1998). During the RE episode, 6-month-old infants displayed a similar amount of negative affect (i.e., anger and sadness) as in the SF episode (Weinberg & Tronick, 1996). However, the same infants expressed more joy during the RE episode than the SF episode and the FP episode. It is thought that the stress caused by the caregiver's unresponsive behavior during the SF episode results in the infant's continued negative affect displayed during the RE episode. This phenomenon is known as the reunion effect (Adamson & Frick, 2003).

Some research has also examined the physiological response patterns of infants during the SFP. Findings indicated that during the SF episode, 5- and 6-month-old infants' heart rate increased, and they showed vagal withdrawal, as indicated by a decrease in respiratory sinus arrhythmia (RSA), as compared to the baseline rates (Moore & Calkins, 2004). While vagal withdrawal is associated with greater negative affect and increased heart rate in the context of the SFP, it is thought to be an adaptive neural-driven stress response, which allows the infant to use bodily resources to meet the increased demands of the situation (Moore & Calkins, 2004). Although less research has examined patterns of physiological responses shown by parents during the SFP, previous studies have indicated that mothers' RSA increased from baseline to the SF episode, the opposite of the response shown by infants (Moore et al., 2009). While there has been extensive research regarding general patterns of change in affect and physiology for parents and infants across the SFP, second-by-second changes have been relatively understudied. However, the patterns provide a basis of what behavior can be expected during the SFP and, broadly, what one might expect in terms of parent-infant synchrony.

During the SFP, affective synchrony is typically not examined during the SF episode, given that parents are instructed to maintain a neutral expression. Therefore, the primary focus of many studies examining synchrony are the FP and RE episodes. Furthermore, some studies with the SFP specifically focus on the dyadic responses during the RE episode, given that it is known as a reparatory interaction between the caregiver and infant (Weinberg & Tronick, 1996). Measurement of individual physiological responses and infant-caregiver synchrony during the SFP may provide further useful information for the SF episode, which is less frequently examined.

Affective Synchrony

One form of synchrony, which has been well-studied, is affective synchrony. Affective synchrony refers to the association between behaviors (e.g., gaze, tone of vocalizations, facial expressions) in infant-caregiver dyads. Some theorists suggest that positive affect is a requirement for interactional synchrony and do not attempt to measure synchrony unless positive affect is present, whereas others do not have such requirements (Harrist & Waugh, 2002).

Several researchers have adopted the well-established Monadic Phases (Tronick, Als, & Brazelton, 1980) system of second-by-second coding as an index for affective synchrony, which collapses level of arousal, gaze, facial expression, and body orientation into several parent and infant phases that fall within a continuum to examine overall affective dyadic synchrony. These phases include protest, avert, object attend, social attend, object play, social play, and talk, and are intended to provide ratings of engagement which range from negative to positive. However, other studies have utilized methods, such as second-by-second coding of facial affect, touch, or gaze synchrony (e.g., Beebe et al., 2007; Chow et al., 2010). Some researchers suggest the importance of investigating various modalities of individuals' affect states separately for a better understanding of caregiver-infant interactions (Beebe et al., 2007). The current study thus proposes examining the specific modalities of affect and heart rate for second-by-second examination of synchrony.

Despite its apparent importance to development of emotion or self-regulation, results from previous research indicated that only about 30% of the interaction time spent in play between mothers and their 3-, 6-, or 9-month-old infants was synchronous, or matching, during the FP episode of the SFP (Tronick & Cohn, 1989). This percentage may increase during toddlerhood interactions (Harrist, Pettit, Dodge, & Bates, 1994). Subsequent episodes were not analyzed in the aforementioned study and have not been analyzed for synchrony percentages in any previous studies, to the knowledge of the author. Furthermore, while interactions were analyzed on a micro-level (i.e., in .25 s frames), the Monadic Phases utilized in calculation of these percentages represent a combination of affective modalities and differ slightly between parents and infants. Therefore, percentage of affective synchrony may be greater when examining facial affect, or any single modality. These findings are consistent with research that suggests a mid-range level of maternal behavior contingent to the infant's facial affect expression may produce the most optimal outcomes.

Predictors of Affective Synchrony

Given the positive outcomes associated with parent-infant synchrony, establishing predictors may allow for better facilitation of synchrony, and thus, better outcomes for the child (Lundy, 2002). Belsky's (1984) model of parenting suggests that both child factors and parent factors determine parenting behavior. In accordance with this theory, one might expect that child and parent factors predict dyadic synchrony. Few studies, however, have examined predictors of dyadic synchrony.

Limited research has provided some information regarding parent-related predictors of affective synchrony. One of the most prominently studied of these predictive factors is maternal level of depressive symptoms. Depressed mothers tend to exhibit flat affect and low levels of stimulation of their infants during interactions compared to their non-depressed counterparts (Field et al., 1988). There are conflicting findings for the level of affective synchrony in depressed and non-depressed mother-infant dyads. For instance, mothers with greater levels of depressive symptoms exhibited less interactional synchrony, as measured through three steps of contingent responsiveness within 15 s, with their 6-month-old infants (Lundy, 2002).

Furthermore, greater maternal depressive symptoms were associated with decreased synchrony of gaze (Beebe et al., 2008). Findings from another study suggested that non-depressed mothers exhibited greater overall affective synchrony of Monadic phases with their 3-month-old infants, but depressed mothers and their infants matched more frequently in negative engagement phases (Field, Healy, Goldstein, & Guthertz, 1990; Tronick et al., 1980). However, at least two more studies have found that depressed mothers are more synchronized with their infants in facial expressions during interactions (Beebe et al., 2008; Lotzin et al., 2016). Lotzin and colleagues (2016) demonstrated that this association was mediated by maternal emotion dysregulation, further implicating the role of synchrony during interactions as contributing to infants' development of emotion regulation skills. The finding that infants and mothers match facial expressions more often when mothers are depressed may suggest that both infants and their caregivers are expressing more facial negativity or neutrality. This is consistent with past research, which suggested that 2-month-old infants and their depressed mothers expressed lower levels of positive affect than non-depressed dyads, but both groups exhibited similar levels of within-dyad contingent behavior (Cohn, Campbell, Matias, & Hopkins, 1990). This relationship may persist across infancy, as a similar relationship was found for maternal depressive symptoms and facial affect synchrony with 3- to 5-month-olds (Aktar, Colonnesi, De Vente, Majdandžić, and Bögels, 2017). Given the divergent findings on level of maternal depressive symptoms and mother-infant synchrony, the current study may provide further evidence as to whether depressive symptoms relate to lower or higher levels of physiological and facial affect synchrony.

Multiple child characteristics have also been related to dyadic synchrony. For example, infants who were born pre-term had lower levels of dyadic synchrony during interactions with the mother between 3 and 9 months of age (age-corrected), when compared to infants who were born at full term (Feldman, 2006; Lester, Hoffman, & Brazleton, 1985; Montirosso et al., 2010). Child gender was another factor associated with level of facial affect synchrony, with mothers and their 3-month-old male infants sharing more positive facial expressions than mothers and their female infants (Weinberg, Olson, Beeghly, & Tronick, 2006). For mothers reporting few or no depressive symptoms, mother-infant dyads consisting of a male infant exhibited greater synchrony of facial affect than dyads with a female infant (Weinberg et al., 2006). Finally, the degree of affective synchrony was found to be greater for father-son dyads than father-daughter dyads, and both mothers and fathers with infants of the same gender were able to re-establish synchrony more quickly after a behavioral mismatch (Feldman, 2003). The current study examined the characteristic of child gender as a factor with the potential to influence parent-infant levels of physiological and facial affect synchrony.

Outcomes of Affective Synchrony

Self-regulation has been defined in many ways, but generally speaking, it is the ability to adapt one's behavior in response to the demands of the environment without the necessity of an external monitor or influence, while also taking into account cues of social acceptability (Kopp, 1982). One specific component of self-regulation is emotion regulation, which involves modulating the expression of affect. Individuals from the United States tend to rate certain emotions (e.g., happiness) as more socially acceptable to display than others in a variety of situations (e.g., anger; Matsumoto, 1990). As children get older, they also report expressing negative emotions such as anger and sadness less than younger children (Zeman & Garber, 1996). In its most advanced form, this ability to control expressed emotions requires more advanced cognitive functioning on the part of the child and, therefore, begins to emerge around 3 years of age.

Parenting behavior is associated with children's later self-regulation abilities. Specifically, previous research has proposed that interactions in which the parent is more responsive or contingent in response to the infant play a key role in the development of emotion regulation (Calkins, 1994). Self-regulation is thought to develop through interactions with the caregiver because those interactions bring awareness to the child of the consequences of their own actions or behavior, in the form of the caregiver's response (Hubley & Trevarthen, 1979; Kopp, 1982). Greater contingency between an infant's and parent's behavior may thus lead to better self-regulation by allowing the infant to recognize their own ability to influence the environment through their own behavior. Parent-child synchrony may also predict a child's ability to self-regulate beyond infancy and toddlerhood. Previous research with mother-infant dyads supports this hypothesis. For instance, affective synchrony of Monadic phases when infants were 3 and 9 months old, as well as the amount of time it took the members of a dyad to reach synchrony initially, predicted increased self-control levels of children at 2 years of age (Feldman et al., 1999). Furthermore, mothers and children who exhibited greater levels of mutually responsive orientation, a construct very similar to synchrony, when the child was 7 to 25 months of age showed greater self-regulation when the child was 4 years old (Kochanska et al., 2008). It is important for researchers to understand emotion regulation and factors which contribute to its development because of the wide range of positive outcomes associated with better emotion regulation ability, such as greater social competence and improved academic achievement (Graziano et al., 2007; Penela et al., 2015). Furthermore, a lack of regulatory strategies and ability may lead to psychopathology, such as externalizing disorders (Eisenberg et al., 2001). The current study thus examined higher mother-infant affective synchrony as a potential predecessor to greater ability of the child to self-regulate at age 3.

Physiological Synchrony

Of the various modalities in which synchrony can be expressed, physiological synchrony during parent-child interactions has been relatively infrequently studied. This is partially because equipment and techniques for obtaining physiological data, especially with infants, have only been widely available in the last few decades. Various types of synchrony during early infancy may provide the foundation for future social interactions and the development of self-regulation. Previous research suggests physiological synchrony, measured as coordinated changes in average heart rate, was associated with better outcomes for infants (e.g., Zelenko et al., 2005). Therefore, the researcher found it important to further examine physiological synchrony in parent-infant dyads.

Respiratory sinus arrhythmia (RSA) and heart rate are commonly used measures of physiological synchrony. Respiratory sinus arrhythmia is an indicator of vagal tone or heart rate variability, which also takes respiration into account, during activation of the parasympathetic nervous system (Beauchaine, 2001; Suurland et al., 2016). Vagal tone, or RSA, indicates the level of influence the vagus nerve, which originates in the brain, is exerting on the heart (Porges, Doussard-Roosevelt, & Maiti, 1994). As stated in the polyvagal theory proposed by Porges (1995, 2007), vagal tone is associated with heart-rate control and is suggested to play a role in an individual's responses to stimuli in the environment, as well as homeostatic maintenance.

Respiratory sinus arrhythmia is believed to change with the experience of emotions (Porges et al., 1994). It typically decreases with processes of emotion regulation, whereas heart rate increases (Buss, Goldsmith, & Davidson, 2005). Specific evidence of this was found in 24-

month-olds for whom RSA level was related to both negative affect and increased heart rate during a stress-inducing experience (Buss et al., 2005). Whereas decreased RSA suggests increased attempts at emotion regulation, a lack of lowering values in the presence of a stressor was associated with psychopathology and difficulty meeting the demands of a challenging situation (Beauchaine, 2001; Huffman et al., 1998). Findings from past research have indicated that at 12 weeks of age, infants whose parents reported greater difficulty with self-soothing had lower baseline RSA compared to infants who both exhibited higher baseline RSA, decreased RSA when faced with a stressful task, and were more easily soothed (Huffman et al., 1998). The vagus nerve system is part of the neural basis and control of muscular responses in the face and therefore, studying both affect and physiology concurrently could further elucidate the biobehavioral process of emotion regulation during social interactions (Porges et al., 1994; Porges, 2007).

Additionally, previous research has found that 6-month-old infants and their mothers demonstrated an inverse relationship in their physiological responses while experiencing a social stressor (i.e., the SF episode of the SFP), with RSA for infants showing a decrease, while mothers' RSA increased (Moore et al., 2009; Ostlund et al., 2017). More sensitive mothers and their infants, however, showed more coordinated physiological responses only in the context of the RE episode of the SFP, during which both showed decreases in RSA (Moore et al., 2009). Conversely, for the other infants in the study, RSA increased back to the higher level exhibited during the baseline (Moore et al., 2009). In the same study, more sensitive mothers showed significant decreases in RSA from the baseline to the reunion episode, whereas less sensitive mothers did not. Infants of more sensitive mothers showed a decrease in RSA, whereas infants of more sensitive mothers did not. This may indicate that infants of sensitive mothers were more able to self-regulate their own negative emotions during the reunion, while the infants of less sensitive mothers, who showed an increase in RSA, were returning to the use of the mother as an external regulating mechanism. The mothers and infants who showed a decrease in RSA may have been physiologically preparing for social engagement, one hypothesized function of vagal tone, which has evolved in humans to facilitate social cooperation (Porges & Furman, 2011).

Heart rate is an additional physiological measure associated with emotion regulation, which can provide second-by-second data regarding the state of both parent and infant. Heart rate typically displays an inverse relationship with vagal tone, such that decreases in RSA correspond to increases in heart rate (Buss et al., 2005). While it is theoretically possible to exhibit an increase in heart rate without a decrease in RSA, the physiological response by infants during the SF episode appears consistent across previous research. Therefore, heart rate may be as applicable a physiological measure as RSA and may provide a more sensitive indicator of dyadic synchrony. The use of heart rate may be preferable, given the minimum requirement of 30 s of physiological data to calculate RSA. One study utilized raw heart rate values and found no difference in the level of coherence (i.e., synchrony) between depressed and non-depressed dyads during regular face-to-face interaction (Field, Healy, & LeBlanc, 1989). However, current research regarding physiological synchrony utilized the intervals between heart beats (IBI) as a similar measure (Feldman, Magori-Cohen, Galili, Singer, & Louzoun, 2011). Within that study, mothers and infants showed synchrony in their IBIs during normal face-to-face social interaction (Feldman et al., 2011). While these two studies suggest synchronicity in heart rate, they were both conducted within normal conditions of interaction. It may be even more telling to examine physiological synchrony when the dyad is under stress and then given a chance to recover from the stressful situation, such as in the RE episode of the SFP.

Predictors and Outcomes of Physiological Synchrony

Depressive symptoms have been studied as a predictor of both affective and physiological synchrony of parent-child dyads. Previous research has indicated that both mother-infant dyads containing depressed and non-depressed mothers and 3-month-olds exhibited high levels of synchrony in their heart rate during naturalistic interactions (Field et al., 1989). One major limitation of the finding, however, was that the study utilized a small total sample size of 16 dyads. More recent findings indicated mothers of toddlers who reported greater levels of depressive symptoms showed a higher level of physiological synchrony when stressed, as indexed by rising cortisol levels and hypothalamic-pituitary-adrenal (HPA) circuit activation (Laurent, Ablow, & Measelle, 2011).

These physiological studies suggest that mothers are more, or at least equally, synchronous (under normal conditions) with their infants when they are depressed. There are several possible explanations for these findings. They may reflect the inability of both the infant and their depressed parent to regulate their emotions during a stressful situation. Both the infant and parent may thus be negatively aroused and more physiologically synchronous. This might be a case where a higher level of synchrony is not adaptive. Furthermore, if physiology and affect are typically assumed to be related, this may also lend credence to greater affective synchrony for depressed mother-infant dyads. Other possible factors such as small sample size and the use of broad physiological indices (e.g., average cortisol level) may mean that these findings do not provide conclusive evidence for increased synchrony in depressed mother-infant dyads. More research is necessary to elucidate the relationship between level of depressive symptoms and physiological synchrony.

Few studies have examined the outcomes of physiological synchrony later in the child's life. Greater physiological synchrony measured as more coordinated changes in average heart rate over several episodes of interaction in a double separation/reunion SFP was associated with having a secure attachment relationship (Zelenko et al., 2005). Given that affective synchrony is believed to play a role in the development of self-regulation, one might also expect physiological synchrony to be associated with self-regulation. Affective synchrony has been related to self-regulation in later childhood and therefore, physiological synchrony may also be related (Feldman et al., 1999). Little evidence exists to support or reject this hypothesis.

Infant-Father Relationships

Given that, in the past, mothers were estimated to spend more than double the amount of time fathers did with their children, most child-related research primarily focused on mothers (Pleck, 1997). While mothers typically are more involved with their children than fathers, there has been a consistent increase in the amount of involvement fathers have with their children in multiple capacities, including caregiving, over the last few decades (Pleck, 1997; Yeung, Sandberg, Davis-Kean, & Hofferth, 2001). Findings suggest that fathers in the United States spent approximately 60-80% of the amount of time that mothers did with their young infants in various activities (Yeung et al., 2001). It may be increasingly important to consider the father's role in the child's life and how it shapes their development.

The role of fathers is distinct from that of mothers, which may stem from differences between the interaction styles of mothers and fathers with their children. Across childhood, fathers spend most of their engagement time with their children in play and the total amount of play time is greater with young infants (Yeung et al., 2001). During interactions with their infants, fathers typically elicit more spikes in infant high positive arousal, whereas interactions with mothers are not characterized by such high levels of arousal (Feldman, 2003). Mother-infant play tended to focus on multiple communicative modalities, such as vocalizations and facial expressions, while father-infant play was more object-oriented and consisted of games of a physical nature (Feldman, 2003). The more arousing play infants experience with fathers may provide opportunities for the child to practice regulating their emotions, whereas these opportunities may not be as frequent with mothers. Interactions between fathers and infants differ from those of mothers and their infants in several manners. Therefore, the predictors of infant-father dyadic synchrony may vary significantly from the predictors of mother-infant synchrony.

Predictors and Outcomes of Infant-Father Synchrony

Despite the likelihood that predictors of parent-infant synchrony differ between mothers and fathers, the topic has been studied relatively infrequently. Previous research has found that dyads in which the parent and infant were the same gender (e.g., father and son) exhibited greater interactional synchrony compared to non-gender-matched dyads (Feldman, 2003). Additionally, this increased synchrony was visible through multiple measurements, including the amount of time it took to re-acquire synchrony following a mismatch (i.e., less of a time gap for same-gender dyads) and more mutual guidance of the interaction. The same research suggested similar levels of synchrony during interactions across mother-infant and father-infant dyads.

Given the small number of studies examining father-infant dyadic synchrony, it remains to be seen whether the predictors and outcomes of synchrony—affective, physiological, or otherwise—during infancy are similar to those of mother-infant synchrony. Two predictors, which have been examined in both mothers and fathers are depressive symptoms and marital quality. The existing parenting literature suggests that depressed fathers display more negative parenting behavior and less positive behavior, such as responsiveness, warmth, and sensitivity (Wilson & Durbin, 2010). Furthermore, increased depressive symptoms were found to be associated with lower levels of dyadic synchrony during interactions with 6-month-olds for mothers, but not for fathers (Lundy, 2002).

Marital quality has also been found to spillover from the marital relationship and predict parenting behavior (e.g., Belsky, Youngblade, Rovine, & Volling, 1991; Erel & Burman, 1995). This association may be even stronger for fathers. For instance, fathers of children under 3 years of age exhibited more negativity in parent-child interactions when they reported poorer marital quality; whereas, this association did not exist for mothers (Belsky et al., 1991). Researchers speculated that mothers may be better at compartmentalizing their distress from various parts of their lives, while fathers may have more spillover between areas of their lives, such as work and marriage to parenthood (Belsky et al., 1991). Greater agreement with spouse on level of marital satisfaction also predicted increased sensitivity for fathers during interaction with their 5-month-old infants, but was not a significant predictor for mothers (Feldman, 2000). Additionally, previous research findings indicated that lower marital quality was associated with a decrease in father-infant interactional synchrony, which also accounted for the indirect effects of poor marital quality on infant attachment security for fathers, but not mothers (Lundy, 2002). The current study thus sought to replicate findings that marital or relationship quality is related to parent-child interaction quality, or in this case, greater dyadic synchrony primarily for father-infant dyads (e.g., Belsky et al. 1991; Erel & Burman, 1995; Lundy, 2002).

Another potential factor contributing to dyadic synchrony between fathers and infants is paternal involvement. Both level of father involvement and paternal attitudes towards parenting have been associated with positive child outcomes. For instance, fathers who had more childcentric views of parenting also had children who scored better on cognitive tests (Shears & Robinson, 2005). Fathers who were more involved when the child was 13 months old also had children who were more likely to be securely attached at 3 years of age (Brown et al., 2012). Paternal attitudes regarding the role of the father have been shown to predict the level of involvement the father reports with their 3-5- month-olds (Beitel & Parke, 1998). More specifically, fathers' perceptions of their own skill at care-taking predicted their involvement in both direct (e.g., feeding) and indirect care (e.g., choosing infant's outfits) that they provided for the infant. Increased sharing of childcare activities and level of father involvement on weekends were both significant predictors of paternal sensitivity during parent-infant interactions (Feldman, 2000). While father involvement and attitudes have not been assessed in relation to dyadic synchrony, they may contribute, given their interrelatedness and previous association with paternal sensitivity (Brown et al., 2012; Feldman, 2000).

Only a small number of studies have examined outcomes of father-infant synchrony or similar constructs. Previous findings with fathers and their 7- to 25-month-olds suggested that higher mutually responsive orientation predicted better child self-regulation at 4 years (Kochanska et al., 2008). Therefore, greater father-infant physiological and facial affect synchrony, as with mother-infant synchrony, are expected to predict better self-regulation when children are 3 years old.

Research Questions and Hypotheses

The current study addressed several research questions. The first of these questions was whether levels of facial affect synchrony differed between mothers and fathers with their 6-9-month-old infants during standardized social interactions in a laboratory setting (i.e., the SFP). It was expected that mothers and fathers would not differ overall in their levels of facial affect synchrony with their infants, consistent with previous affective synchrony research (Feldman, 2003). However, levels of synchrony were expected to be greater for dyads in which the father and infant were the same gender (i.e., father-son dyads) as found in earlier research (Feldman, 2003).

As well as examining facial affect synchrony, the current study aimed to determine whether and how levels of physiological dyadic synchrony (changes in RSA and coordination of heart rate) differed between mothers and fathers during interactions in the SFP when the infant is 6-9 months old. This study expanded upon previous research, which primarily utilized RSA values, typically measured in 60 s epochs, by including heart rate, which is considered a more instantaneous measure of physiology. To the knowledge of the researcher, there had been no previous studies examining physiological synchrony with father-infant dyads for the SFP utilizing heart rate. With inadequate previous information, this research question was exploratory in nature. However, the researcher hypothesized that, as with facial affect synchrony, overall physiological synchrony in infant-parent dyads would not vary significantly between mothers and fathers, except when the father and infant were the same gender.

The current study also assessed whether level of depressive symptoms in mothers and fathers were associated with parents' levels of facial affect and physiological synchrony with their infants during the FP and RE episodes of the SFP at 6-9 months. Previous research has shown associations between maternal depression and greater negative infant affect during normal face-to-face play (Cohn et al., 1990; Pickens & Field, 1993). The researcher expected to replicate previous findings, which have shown increased facial affect synchrony between mothers higher in depressive symptoms and their infants (Beebe et al., 2008; Lotzin et al., 2016). Fathers were not expected to have greater facial affect synchrony with their 6-9-month infants during the SFP, even if the fathers displayed higher levels of depressive symptoms. This was due to fathers showing less positive affect than mothers and infants showing less positive affect with fathers than with mothers during free play interactions (Forbes, Cohn, Allen, & Lewinsohn, 2004). Previous research provides mixed evidence regarding whether depressive symptoms affect parents' interactions with the infant differentially. For instance, at 3 months, infants of parents with a history of depression were less likely to display positive affect during the SF episode only when the interaction occurred with their mothers (Forbes et al., 2004). However, at 6 months, the parent's level of positive facial affect during the FP episode of the SFP predicted infant positive affect and this association did not differ by parent gender (Forbes et al., 2004). The observed quality of father-infant interactions did not differ significantly between depressed and non-depressed dyads (Field, Hossain, & Malphurs, 1999). In the current study, physiological synchrony during the SFP was not anticipated to differ significantly with increases in depressive symptoms for either mothers or fathers. This is consistent with previous research indicating no difference in heart rate synchrony between a group of depressed and a group of non-depressed mother-infant dyads (Field et al., 1989). While it was expected that father-infant dyads would not be affected, there was no previous research to reference for father-infant heart rate synchrony. However, given that research suggested more profound effects of depression on mother-infant dynamics, this was the researcher's hypothesis.

Relationship satisfaction was additionally examined as a predictor of maternal and paternal facial affect synchrony and physiological synchrony. Consistent with previous research, it was expected that greater parent-reported relationship satisfaction would be related to level of facial affect synchrony with the infant for fathers, but not mothers (Lundy, 2002). Although this association has not been examined with physiological synchrony, based on the aforementioned study, higher relationship satisfaction was also predicted to be associated with increased physiological synchrony for father-infant dyads only.

In addition, the current study assessed the relationship between levels of facial affect synchrony and physiological synchrony for mother-infant and father-infant dyads when the infant was 6-9 months old as predictors of child self-regulation measured at 3 years of age. It was expected that a higher level of facial affect synchrony and physiological synchrony would be associated with greater self-regulation ability when the child was 3 years old. This association was hypothesized to exist for both mother and father-infant dyads.

Finally, reported levels of father involvement and attitudes towards the role of the father were analyzed as predictors of physiological and facial affect synchrony of father-infant dyads, specifically. Given that they were previously found to be associated with one another, both greater father involvement and more positive views of the role of the father were also hypothesized to be related to increased facial affect and physiological father-infant synchrony from 6-9 months during interactions in the SFP. Self-reported father involvement with the infant at 6-9 months, as well as the father's attitudes regarding the paternal role were examined as predictors of self-regulation when the child was 3 years old. Consistent with previous research indicating that each of these are important predictors of parenting behavior and given that parenting behavior is predictive of synchronous interactions, more positive attitudes about the role of the father, as well as increased levels of father involvement were expected to be positively related to better self-regulation by the child at 3 years of age (Beitel & Parke, 1998; Feldman, 2000).

Method

Participants

One hundred and one families with 6- to 9-month-old infants agreed to participate in the larger longitudinal study. However, of those initial families, the SFP was completed with 98 mother-infant dyads and 91 father-infant dyads. An additional family was dropped from the study sample because parents later reported that the child had been diagnosed with autism spectrum disorder (ASD) and it was unknown how that might bias results of the 6-9-month and 3- year visit (new *n* = 97). The 97 families whom had completed at least the mother-infant SFP were considered the primary study sample.

Demographic data were based on maternal report on forms completed immediately prior to the 6/9-month visit and father reported data were used to supplement if mothers failed to report key demographic variables. The mothers from the study were, on average, 32.25 years old (*SD* = 4.53 years) and the fathers were an average of 34.27 years old (*SD* = 5.78 years). A summary of further demographic data for mothers and fathers, including household income, parent race/ethnicity, and education, can be seen in Table 1. The majority of infants (*n* = 80) completed the first study visit when they were within 2 weeks of turning 6 months old (i.e., 5 ½ months to 6 ½ months old). However, due to recruitment difficulties, an additional subset of families was invited to complete the initial visit when their infants were 8 ½ to 9 ½ months old (*n* = 17). In the study, 50.5% of the infant participants were female (*n* = 49) and 49.5% were male (*n* = 48).

Based on the specific criteria for participation that families had completed the initial 6/9-month visit and had come in for a 2nd visit with either their mother at 12 months, or father at 13 months, approximately 90 families were invited to complete the follow-up visit when the child was 3 years of age. Sixty-three families returned for the preschool visit, which took place when the child was no earlier than one month before their 3rd birthday and no later than their 4th birthday. However, one of those children did not appear to understand the experimenter's instructions in English and therefore, was not considered to have a successful completion of the tasks of interest for the study. Several other participants were excluded from later analyses because they did not complete the emotion regulation task of interest, though they attended the visit and may have completed other tasks.

Table 1

Demographic Data

	Mothers (*n* = 97) %	Fathers (*n* = 97) %
Annual Household Income		
$9999 or less	1.00	1.00
$10,000-$19,999	3.10	3.10
$20,000-$29,999	4.10	4.10
$30,000-$39,999	2.10	2.10
$40,000-$49,999	9.30	9.30
> $50,000	80.40	80.40
Education		
Less Than High School	0.00	1.00
High School	1.00	7.20
Some College Classes	15.50	21.60
2-Year College Degree	3.10	4.10
4-Year College Degree	28.90	40.20
Advanced/Professional Degree	51.50	25.80
Primary Race		
White/Caucasian	91.80	90.72
Black/African American	6.20	8.25
Asian	1.00	1.03
Not Reported	1.00	0.00
Ethnicity		
Hispanic or Latino	16.50	14.40
Non-Hispanic	83.50	85.60

Procedure

Recruitment took place through advertisements in a university online newsletter, at a local fair for expecting families, and through flyers placed on public bulletin boards in family-friendly locations. Interested families were screened to ensure that both parents were living with the infant (i.e., cohabiting) and that infants had a birth weight of 5.5 pounds or greater. Families consisting of adoptive parents were allowed to participate in the study if they had adopted the child within the first few weeks of birth. Parents were compensated with gift cards for their participation in the study, with values commensurate to the amount of time spent in the laboratory and completing questionnaires.

Both mothers and fathers were separately mailed paper copies of several surveys, including measures of demographic information, parental involvement, relationship satisfaction, and parent depressive symptoms to complete prior to the initial laboratory visit. The initial laboratory visit occurred with the mother, father, and infant present. Once each parent had provided informed consent, as well as permission for their child to participate, each of the family members had physiological sensors placed on them. For infants, this was done on a changing table, with a parent present in the room. Infants were placed in white onesies to minimize gender bias in later behavioral coding. The physiological sensors were connected to lead wires, which fed into a small, portable electronic device, or PDA. The PDA connected wirelessly to the computer software, allowing the collection of the physiological data from both the infant and parent.

Prior to the visit, a coin was flipped to determine which parent would complete the SFP with the child first. The procedure for the baseline and SFP were identical for both parents. A 2 min initial baseline for physiological data was completed with the infant sitting in the parent's lap, watching a short video to maintain their attention and avoid movement as much as possible. Then, the infant was moved and secured into a high chair, which rested on an elevated wooden base to allow for an optimal camera angle of the infant's face. Parents were seated in a chair directly in front of and facing the infant. They then completed the SFP, which consists of an FP, SF, and RE episode. Each of the episodes lasted for 2 min, unless the child became distressed for 30 s, in which case the ongoing episode was terminated per protocol. During the FP episode, parents were instructed to play with their infant as they usually would at home. However, parents were not provided any toys for use during the interaction. For the SF episode, the experimenter asked parents to exhibit a neutral facial expression and not to interact with or touch the child. Instructions for the SF and RE episodes were spoken into a microphone and were played over a loud speaker into the experiment room. Finally, for the RE episode, parents were instructed to resume playing normally with their infant. An age-appropriate developmental assessment was completed with the infant following the SFP to provide developmental feedback to the parents. Finally, the family was compensated with a gift card to a local retailer valued at $30 and mailed a DVD of their visit with the child.

As early as 2 weeks prior to the child turning 3 years of age, families were invited back for a follow-up visit. Criteria for families to be invited were that both parents and the child attended the 6-/9-month visit and completed a second visit when the child was either 12 months of age (with the mother) or 13 months of age (with the father). Each parent was sent a personalized link via e-mail to complete a set of online Qualtrics questionnaires prior to their visit. Parents completed an online informed consent form and the same informed consent was reviewed again with parents at the laboratory visit. The online forms consisted of an updated demographics form with questions about the parent and child (e.g., current household income and employment), as well as measures of parent depression, romantic relationship satisfaction, current parental caregiving involvement, and child behavior problems. These forms were particularly intended to allow parents to report any specific changes to their living situation or circumstances, such as a change of romantic partner since the family's most recent visit.

At the preschool visit to the laboratory, both parents and the child were once again present, except in rare cases where the parents were unable to accompany the child together. First, each parent separately completed a puzzle with the child in a randomized order determined by a coin flip prior to the visit. Next, the child had the same pediatric physiological sensors placed on them as they did at the 6/9-month visit while at least one parent was in the room. Both physiological data and video footage were recorded via a portable PDA using Mindware Biolab software. The child remained in the room with the experimenter for the duration of the visit. They were first shown a short neutral video of nature scenes, which lasted approximately 2 min, to obtain a sitting baseline of physiological measures. Next, the child was administered the Peabody Picture Vocabulary Test (PPVT), so that the researchers could provide developmental feedback to the parents. The child then completed a series of short game-like tasks, intended to invoke the child's use of self-regulation skills. Following the completion of the visit, children could choose a small toy from a selection of prizes for their participation in the study. Additionally, each family was compensated for their time and participation with a $50 gift card to a local retailer and mailed a DVD recording of their child's visit.

Measures

Infant facial affect. Infant facial affect was coded in 1 s intervals for the duration of the FP, SF, and RE episodes of the SFP by trained coders. The rating scale for facial affect exists on a continuum from extreme negative affect, -3, which was full distress or crying, to very positive affect, 3, which was laughing or broadly smiling. This affect coding system has been used in previous research with young infants (Braungart-Rieker et al., 1998). Reliability coding was conducted on at least 20% of random videos. The intraclass correlations (ICC) for intercoder reliability of infant affect during the SFP with the father for each the FP, SF, and RE episodes were .93, .96, and .95, respectively. For infant affect during the SFP with the mother, the values for each respective episode were as follows: .94, .95, and .96. Some participants from the study did not have infant affect data because parents were unable to complete the SFP with their infants if the infant was distressed. Additionally, a technology error occurred with the camera equipment, which meant that there were no videos from the initial visit to code infant affect for one family.

Parent facial affect. Parent facial affect was coded in 1 s intervals for the FP and RE episodes. However, facial affect was not coded for parents during the SF episode, as they were requested to intentionally maintain a neutral face during that time. Coding was completed using the same negative to positive rating scale as infant facial affect, with some modifications for adults. In this case, -3 represented an overly exaggerated sad face, whereas 3 was described as an overly exaggerated positive facial expression with a large smile. Primary and secondary coders overlapped on 20% of videos randomly to establish reliability in coding. For father facial affect during the FP, the reliability ICC from coding was .92, while the reliability ICC for the RE was .99. Mother facial affect ICCs for reliability were .98 for the FP and .92 for the RE. There was no parent affect data for several dyads because some infants became upset and were unable to complete the SFP with both parents. One additional family had no videos for affect coding because of an issue with the computer recording software.

Physiological activity. At the 6/9-month visit, seven electrodes were attached to each the infant and both parents on the torso, neck, and back. Small, portable devices (MindWare mobile impedance cardiographs) were used to monitor physiology and MindWare Biolab computer software was utilized to collect the signal from these electrodes at a sampling frequency of 500 Hz. Data collected include electrocardiogram (ECG), skin conductance or electrodermal activity (EDA), and respiration signals. The collected data was cleaned by a primary coder who opened each file and visually examined errors detected by MindWare Heart Rate Variability (HRV) software algorithm, which was intended to detect heart beats. For the infants' physiology analysis, bandwidths were set at .003 to .040 Hz for the VLF band, .040 to .240 Hz for the LF band, and .240 to 1.040 Hz for the HF/RSA band. For the parents' physiology analysis, the VLF bandwidth was the same, but the LF bandwidth ranged from .040 to .120 Hz and the HF/RSA bandwidth ranged from .120 to .400 Hz. The data was examined for movement or other artifact and, if present, falsely detected peaks due to artifact were removed. From these measures, the MindWare HRV software, HRV Analysis version 3.1.3 was used to determine values for raw heart rate, respiratory sinus arrhythmia (RSA) for each period of 60 s, and the length of time between heart beats, which is known as the inter-beat interval (IBI). Sample sizes for physiological synchrony varied between parent and episode for several reasons. First, several fathers were unable to complete the SFP with their infants due to the infants' fussiness. During cleaning of physiology data, some participants' data for certain episodes of the SFP was found to be not viable and excluded from further analyses, either because the episode from the SFP was less than 30 s or because the physiology data was messy due to movement artifact and could not be sufficiently cleaned for analysis. Criteria for inclusion were that no more than 10% of the data had to be edited from the analyses completed by the Mindware HRV software (MindWare

Technologies, 2018). Primary and secondary coders overlapped for reliability purposes on at least 20% of the cleaned physiological data. Following a procedure used by previous researchers, reliability was considered achieved if RSA values of the primary and secondary coders were no more than .1 away from each other (Scrimgeour, Davis, & Buss, 2016).

Parent depressive symptoms. Parent depressive symptoms were measured using the self-report measure of the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). Example items include, "I felt sad" and "I did not feel like eating, my appetite was poor." The response Likert-type scale for this measure is 4-points from ranging from 0 (*rarely or none of the time*) through 3 (*most or all of the time*) for 20 items. Scores on the CES-D range from 0 to 60, with a score of 16 indicating a probable clinical level of depressive symptoms. This self-report measure was completed by both parents at the 6/9-month visit. Internal consistency was $\alpha = .74$ for fathers and $\alpha = .81$ for mothers on the CES-D.

Relationship satisfaction. The Couples Satisfaction Inventory (CSI; Funk & Rogge, 2007) was completed by both parents as a measure of relationship satisfaction when the infant was 6/9 months old. Sample items include, "I can't imagine ending my relationship with my partner" and "For me, my partner is the perfect romantic partner." The CSI is a 32-item measure, with most questions answered on a 6-point Likert-type scale from either 0 (*not at all true*) through 5 (*completely true*). A higher total score on the measure indicates a greater level of relationship happiness. Consistency for this measure at the 6/9-month visit was high, with Cronbach's $\alpha = .96$ for mothers and .96 for fathers.

Father involvement. Paternal involvement during infancy was measured using the Who Does What Questionnaire (WDW; Cowan & Cowan, 1988). On this measure, a higher score indicates that more tasks are completed by the father and lower scores indicate that the mother primarily completes a task. Specifically, the scale ranges from 1 (*she does it all*) to 9 (*he does it all*) for each activity. Therefore, a higher score suggests greater father involvement in child-related activities. These activities include a range of caregiving activities, such as "Feeding the baby" and "Doing the baby's laundry." While the questionnaire includes 12 items regarding the times during which each parent is involved in activities (e.g., weekdays or weekends), only the 11 items listing specific activities were used for the purposes of the current study. The internal consistency for this sample of fathers was $\alpha = .66$.

Paternal attitudes. Attitudes pertaining to the importance of the paternal role were assessed using the self-report Role of the Father Questionnaire (ROFQ; Palkovitz, 1984). This measure takes self-report of the attitudes fathers have about being involved, effective fathers. The ROFQ consists of 15 questions on a 5-point Likert-type scale (e.g., "A father should be as heavily involved in the care of a baby as the mother is", "It is essential for children's well being that fathers spend time interacting and playing with their children"). Responses fall on a spectrum from disagree strongly (1) to agree strongly (5). Higher scores represent a more positive view of the importance of the father's role and father involvement. When completed by fathers in the current study, the internal consistency for this measure was $\alpha = .79$.

Child self-regulation. Three-year-olds completed an emotion regulation task called the Attractive Toy in a Transparent Box Task, or Lock Box Task for short (Goldsmith, Reilly, Lemery, Longley, & Prescott, 1999). This task required the child to complete a potentially frustrating or anger-inducing task, despite a lack of help from the experimenter. This is a commonly used task for the preschool age group and was taken, along with a behavioral coding system guide, from the Preschool version of the Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith et al., 1999).

In the Attractive Toy in a Transparent Box Task, child participants were first given an option of toy to play with (either a talking and noise-making dinosaur from the Disney movie the Good Dinosaur or a singing Elsa doll from the Disney movie Frozen). The child was allowed to play with the toy briefly to peak their interest, while the experimenter used a stopwatch to time 60 s. Then, the experimenter placed the toy in the transparent, locking box and placed a lock on it. The child was given a ring of several keys that did not open the lock and instructed to use those keys to attempt to open the box to play with the toy once the experimenter left the room. Prior to leaving, the experimenter demonstrated placing a key in the lock hole and attempting to turn the key to unlock the lock. The experimenter then left the room for 4 min while the child attempted to unlock the transparent box.

For the Lock Box task, the child's response behavior was coded manually based on a review of the video footage from the study. Children were coded separately on intensity of anger facial expression and intensity of sadness facial expression using the same scale from 0 (*no facial region showed codeable anger or sadness*) to 3 (*an impression of strong anger or sadness due to facial region changes*). Their intensity of frustration during the task was also coded with the following scale: 0 = *no detectable frustration*, 1 = *mild/ambiguous frustration*, 2 = *child is clearly frustrated*, or 3 = *intense or extreme frustration*. Presence of bodily anger, presence of bodily sadness, and presence of protest vocalizations were each coded as a dichotomous variable, being either present (1) or not (0). At least 20% of Lock Box Task videos were coded for interrater reliability. Since the presence of bodily anger and presence of bodily sadness codes occurred infrequently they were excluded from calculation of the composite emotion regulation variable. Each child's composite emotion regulation variable value was computed by summing the Z scores of each child's mean facial anger intensity, mean facial sadness intensity, mean frustration level, and the proportion of time during which the child made protest vocalizations during the Lock Box Task. Therefore, a higher score on this variable indicated worse emotion regulation, whereas lower scores indicated better emotion regulation. Due to non-normality, the emotion regulation variable was transformed by adding a constant to eliminate negative and zero scores, then the log 10 function was used to take the log of each score.

Data Analysis Plan

Attrition analyses. Initially, attrition analyses were conducted to determine whether families who dropped out of the study (did not complete a 6/9-month and a 12- or 13-month visit) differed significantly on demographic variables (i.e., household income, parent race, parent education level, child race, or child gender). Chi-square analyses were utilized for categorical demographic variables, including child gender, household income, child race, parent race, and parent education. One-way between-subjects ANOVAs were used to detect differences between the two groups for continuous demographic variables, including child and parent age.

Covariate analyses. Next, covariate analyses were run for child age (6 or 9 months) at the initial visit, parent order of completion of the SFP with the infant (mother or father first), and demographic variables. For all sets of covariate analyses, chi-square analyses were once again used to check for significant relationships of possible categorical covariates with categorical dependent variables and one-way between-subjects ANOVAs were used to check continuous dependent variables. If the potential covariate was a continuous variable (only true of child age and parent age), bivariate Pearson correlations were computed between the covariate and outcome variable. Outcome variables included the level of parent-infant synchrony for both mother- and father-infant dyads during the FP and RE episodes of the SFP, as well as children's emotion regulation scores at the time of the preschool visit.

First, analyses were conducted to determine whether 6- or 9-month-olds from the sample differed significantly on any of the dependent variables and thus, whether infants of both ages could be tested as one group or if age needed to be controlled for in subsequent analyses. A dichotomous age variable was created to examine whether differences existed between infants whose first visit was at 6 months, as compared to those who had the first visit at 9 months. Further covariate analyses were completed to determine whether the variables of interest differed significantly by household income, parent race, parent education level, child race, or child gender. If they did differ, those variables were controlled for in subsequent analyses.

Computation of parent-infant synchrony variables. Prior to testing research questions involving parent-infant physiological and facial affect synchrony, a variable for degree of synchrony between each parent-infant dyad during each episode of the SFP was computed using time series analysis. Time series analyses utilizing an ARIMA (AutoRegressive Integrated Moving-Average) framework for modeling allow the researcher to calculate the relatedness of values in two time series (e.g., parent and infant) by combining past values from the first time series (autoregressive component), as well as values from another times series (Pickup, 2014). This type of analysis is sometimes called the Box-Jenkins model, after some of the original researchers to use the method. ARIMAX models, in particular, can account for exogenous variables (e.g., other time series) as predictors of the time series of interest. Therefore, this type of model takes into account the non-independence of the data with itself (i.e., autocorrelation) in one time series (e.g., the infant's facial affect) and with another time series (e.g., the parent's facial affect).

Time series analyses were conducted using the SAS version 9.4 in English. Several steps were taken to create a synchrony variable for facial affect and a separate one for physiology, which indexed the strength of the relationship between parents' and infants' facial affect or physiological time series. Data was prepared using the time series data preparation functions in SAS, which create a time index variable and re-format the data to a format readable by the SAS program. Additionally, some data cleaning was necessary, which was also completed in the SAS program. Parent and infant affect data were considered uncodeable for 1 s segments in which the individual's face was not visible. If more than 10% of data was marked uncodeable by the rater, then data for that episode was not included in synchrony analyses. If less than 10% of affect data was missing, a technique previously used by other researchers for replacing missing data in time series data preparation was used, in which missing values were replaced with the last non-missing value of the time series (Roth, 1994).

For all synchrony computations, an ARIMA model was first fit to the infant's time series with the assistance of the SAS Time Series Forecasting System (TSFS). The TSFS suggests parameters for the ARIMA model and provides model fit and diagnostic statistics to compare models. The ultimate goal of fitting a model to a time series is to account for all the components of signal and reduce the variability to unpredictable white noise. The specified parameters of the model are intended to parse out the autocorrelated and trend components of the time series, as well as adjusting the series by differencing, if necessary. Stationarity, which indicates a constant mean and variance of the time series in question, is a necessary prerequisite for ARIMA modeling. Differencing, which is taking the difference between two values in a time series as a new time series, is used when series are not stationary. Once a sufficient model had been fit, SAS Studio was used to input the parameters of the ARIMAX model (ARIMA with exogenous predictors) with the inclusion of the parent's time series as a predictor. This allowed SAS to filter the two time series based on the ARIMAX model and provide correlation values between the residuals of the two time series. Specifically, SAS provided a cross-correlation function (CCF) plot as output, which indicated the numeric value of the correlations between two time series at various lags (see Figure 1 for example). The CCF plot indicated a shaded area, which represented the 95% confidence interval region, such that only correlations which fell outside of that shaded region were considered significant. Given that synchrony most likely occurred at lagged intervals, the largest value of a CCF was taken from the CCF plot, regardless of whether the lag was positive, negative, or zero. That CCF served as the parent-infant dyad score for synchrony for either facial affect or physiological synchrony for the respective episode of the SFP.

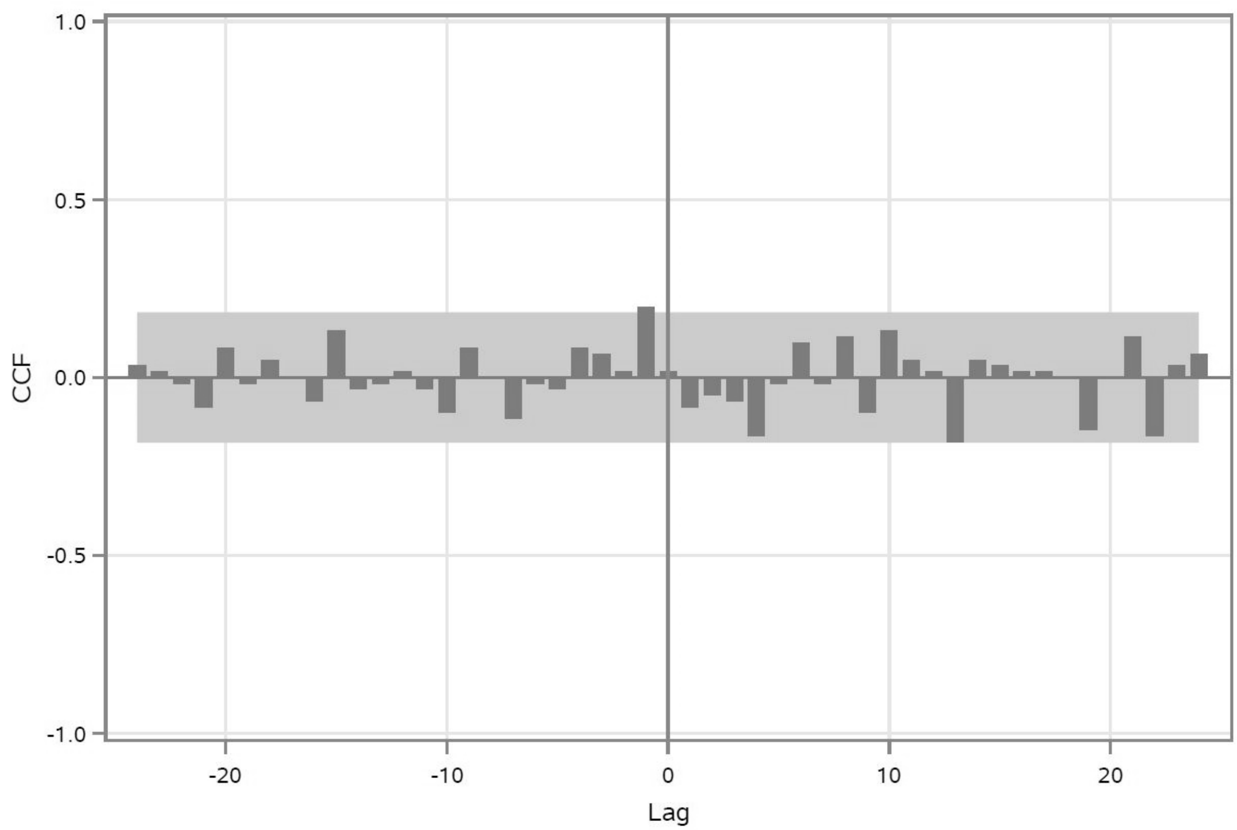

Figure 1. Example of a Cross-Correlation Function Plot. Shaded area represents two standard error limits. Bars that reach outside of the gray area are statistically significant, $p < .05$.

Differences in synchrony with each parent. The first major research question had two components. The first was whether levels of facial affect synchrony differed between mother-infant and father-infant dyads. The second was whether parent-infant physiological synchrony differed by parent gender. In order to address these two questions, levels of facial affect synchrony and physiological were computed for each dyad as a CCF. The values of those CCFs were then compared in a one-way repeated measures generalized linear model (GLM), specifically, an ANOVA. Covariates were included, as deemed necessary in covariate analyses. Next, the level of parent-infant physiological synchrony was examined in two ways. The first is that change in the average RSA values for each episode of the SFP for both the parent and infant were compared. For instance, the researcher examined whether both the infant and parent showed a positive change in RSA from the FP episode to the SF episode of the SFP. However, one pitfall of utilizing RSA as a physiological measure is that it does not provide second-by-second output. The generally accepted rule is that RSA must be measured across a period of at least 30 s to obtain a valid measurement. Many studies implement this by using averages of either 30 or 60 s intervals for statistical analyses (Buss et al., 2005; DeGangi, DiPietro, Greenspan, & Porges, 1991). Therefore, it is apparent that using RSA does not allow for a full microanalysis of dyadic interactions, rather, it can only represent changes in an individual's response over larger time spans. Consequently, the current study utilized changes in average RSA from one episode to the next as a measure of coordination in physiology between parents and infants. However, the current study went beyond that to obtain and compare second-by-second physiological data, in this case, raw heart rate. Time series analysis of the parent and infant heart rates for the FP and RE episodes of the SFP were conducted. A CCF was computed for each dyad and the values of those CCFs were then be compared in a one-way repeated measures GLM, as with facial affect.

Predictors of synchrony at 6/9 months. The second major aim of the current study was to determine the within-age predictors of facial affect and physiological synchrony. Potential predictors included the parent's level of depressive symptoms and relationship happiness. The scores of each parent on these self-report inventories were used in linear multiple regressions with parent-infant facial affect synchrony and physiological synchrony at 6/9-months as outcomes. Mother-infant and father-infant dyads were tested separately with each of these predictors in the model, as were facial affect and physiological measures.

Predictors of child emotion regulation. The next goal of the study was to examine factors from 6/9-months that contributed to the development of later self-regulation (i.e., at age 3). A composite emotion regulation score was calculated based on the child's performance during the emotion regulation task at the follow-up visit when the child was 3 years old. This score served as the outcome in several multiple regressions. In the first, the CCFs of mother-infant facial affect synchrony and physiological synchrony at 6/9-months were tested as predictors, and the father-infant facial affect and physiological synchrony CCFs were tested using a separate identical model.

Finally, the current study examined specific father-related predictors of synchrony and self-regulation. This involved examining a multiple regression with the total score from the self-report measures of father's level of father involvement and paternal attitudes about the role of the father in relation to the dependent variables of facial affect and physiological synchrony at 6/9-months. Furthermore, to test the association between father involvement and paternal attitudes with child self-regulation, the measures from the 6/9-month visit were used to predict the self-regulation composite at the 3-year visit.

Results

Descriptive Statistics and Attrition Analyses

Descriptive statistics for primary variables of interest can be found in Table 2. Chi-square analyses did not indicate significant differences by parent race, parent education, child race, or household income between families who came only for the infant visit (6/9 months) and those who completed the entire study (see Table 3), *p*s > .05. However, families of female children were more likely than families of male children to return for the visit when the child was 3 years of age, $\chi^2(1) = 3.92$, $p < .05$. There were also no significant differences in child, $F(1,96) = .35$, $p = .56$, maternal, $F(1,96) = 1.21$, $p = .27$, or paternal age (at the time of the initial visit), $F(1,96) = 1.31$, $p = .26$, between those who remained in the study and those who dropped out.

Table 2

Descriptive Statistics for Study Variables

Variable	*N*	*M*	*SD*
FP Affect Synchrony (Father)	74	.22	.06
RE Affect Synchrony (Father)	71	.23	.06
FP Affect Synchrony (Mother)	79	.23	.06
RE Affect Synchrony (Mother)	75	.23	.07
FP Heart Rate Synchrony (Father)	72	.24	.08
RE Heart Rate Synchrony (Father)	70	.25	.09
FP Heart Rate Synchrony (Mother)	74	.22	.08
RE Heart Rate Synchrony (Mother)	72	.22	.05
Maternal Depressive Symptoms	97	6.95	5.82
Paternal Depressive Symptoms	91	6.59	4.86
Maternal Relationship Satisfaction	94	136.83	20.61

Variable	*N*	*M*	*SD*
Paternal Relationship Satisfaction	90	136.54	20.65
Father Involvement	92	3.43	.91
Fathering Attitudes	92	63.42	5.40
Child Emotion Regulation	53	.54	.28

Table 3

Attrition Analyses

Variable	χ^2	*df*	*p*
Maternal Race	2.36	3	.50
Paternal Race	.58	2	.75
Maternal Education	4.08	4	.40
Paternal Education	2.67	5	.75
Child Gender	**3.92**	**1**	**.05**
Child Race	.54	1	.46
Household Income	10.10	5	.07

Note. Bolded values are significant at $p < .05$.

Parent-Infant RSA Changes

The current study sought to examine changes in RSA from episode to episode of the SFP for parents and infants. For mothers, there was a significant main effect of episode of the SFP on average RSA value, $F(1.80, 138.26) = 8.53$, $p = .001$, $\eta_p^2 = .10$, observed power = .95. Due to a violation of sphericity and an Epsilon statistic value of greater than .75, the Huynh-Feldt correction was used. Pairwise comparisons using a Bonferroni correction indicated that there was a non-significant increase in maternal RSA from the FP to SF, $p = .25$, a significant decrease from the SF to RE, $p = .002$, as well as a significant decrease from the FP to the RE episodes, $p = .02$. Infants also had a significant main effect of SFP episode on RSA values during the SFP with the mother, $F(2, 146) = 4.48$, $p = .01$, $\eta_p^2 = .06$, observed power = .76. The only significant change in their RSA, however, was a decrease from the FP to SF episodes, $p = .01$. Neither infants, $F(2, 138) = 1.23$, $p = .30$, $\eta_p^2 = .02$, observed power = .26, nor their fathers, $F(1.83, 135.34) = 2.26$, $p = .11$, $\eta_p^2 = .03$, observed power = .32, showed significant changes in RSA by SFP episode.

Parent-Infant Heart Rate Synchrony

Initially, CCF plots were generated for the filtered facial affect and heart rate time series for each dyad. The following is a description of the results from those CCF plots, which indicated levels of dyadic synchrony. Analyses involving synchrony were first carried out using all dyads with usable synchrony data, regardless of whether the dyad's synchrony correlation values reached significance on the CCF plot. Analyses were later repeated using only those dyads that achieved a significant level of synchrony. For the FP episode with mothers, 61 out of 78 dyads in the FP and 44 out of 75 dyads in the RE reached significant levels of facial affect synchrony. Physiological data was available for 74 mother-infant dyads, and 48 reached a significant level of heart rate synchrony during the FP. For the RE, 45 of 73 mother-infant dyads experienced significant levels of heart rate synchrony. For fathers, 74 father-infant dyads had usable facial affect data from the 6/9-month visit FP episode with which to compute synchrony. Of those, 51 reached a significant level of synchrony. For the RE, 48 out of 71 infant-father dyads achieved a significant degree of facial affect synchrony. Out of 72 possible infant-father dyads during the FP, 55 of those had significant heart rate synchrony. During the RE, 50 out of 71 possible dyads achieved significant levels of heart rate synchrony.

Covariate Analyses for Within-Time Measures

As mentioned previously, the first set of presented results are for all dyads, including those who did not reach a significant level of synchrony during a given episode of the SFP. All variables were checked to see if 6- and 9-month-olds could be tested as one group or whether there were differences between the two age groups. Then, levels of synchrony at the 6/9-month visit were examined to determine if covariates were necessary to include.

Level of father involvement differed by age (6 or 9 months), with fathers showing more involvement with 9-month-old infants, $F(1,90) = 5.09$, $p = .03$. Therefore, age was included as a covariate for all analyses including father involvement. Child gender was significantly related to mother-infant heart rate synchrony during the RE episode, $F(1,70) = 5.12$, $p = .03$, with female infants having greater synchrony with mothers. Therefore, child gender was included as a covariate in subsequent analyses of mother-infant heart rate synchrony during the RE, except when child gender was the primary predictor in the research question being tested (i.e., when comparing same-gendered dyads to non-same gendered dyads). Household income was significantly associated with infant-mother affect synchrony during the FP episode, $F\ (5,73) = 2.74$, $p = .03$, and degree of heart rate synchrony for fathers in the FP episode, $F\ (3,68) = 2.93$, $p = .04$. Child race was also related to dyad facial affect synchrony for the mother-infant FP episode, $F\ (1,77) = 7.83$, $p = .01$, such that White/Caucasian infants displayed greater synchrony with mothers than infants in Black/African American dyads. Correlations of synchrony outcomes with the possible continuous covariates of maternal, paternal, and child age at the first visit were not significantly related with few exceptions. Child age at the first visit was significantly and inversely related to mother-infant physiological synchrony for all dyads during the FP episode,

$r = -.24$, $p = .04$. Paternal age was significantly and inversely associated with father-infant physiological synchrony during the RE episode, $r = -.28$, $p = .02$.

Parent and Gender Differences in Facial Affect Synchrony for All Dyads

First, infants from all dyads, including those that did not achieve a degree of significant synchrony were compared in degree of synchrony with mothers and fathers. Then mother-infant and father-infant dyads with the same gender parent and infant were compared to those where the parent differed from the infant were separately tested for synchrony level differences. Results of repeated measures ANOVAs with a within-subjects factor of parent (mother or father) showed that infants had similar levels of facial affect synchrony with mothers and fathers during FP at the 6/9-month visit, while controlling for the between-subjects factors of household income and child race, $F(1, 57) = 1.42$, $p = .24$, $\eta_p^2 = .02$, observed power = .22. A separate repeated measures ANOVA with no covariates indicated there were no significant differences between infant-mother and infant-father facial affect synchrony during the RE episode, $F(1, 59) = .06$, $p = .80$, $\eta_p^2 = .001$, observed power = .06.

There were no significant differences between mother-infant dyads of the same and different genders in facial affect synchrony for the FP episode, while controlling for household income and child race, $F(1,66) = .20$, $p = .66$, $\eta_p^2 = .003$, observed power = .07. Facial affect synchrony during the RE episode also did not differ between same and different gender mother-infant dyads, $F(1,73) = .10$, $p = .75$, $\eta_p^2 = .001$, observed power = .06, when tested with a one-way between-subjects ANOVA. Additional analyses comparing father-infant dyads of the same gender to those of different genders showed non-significant differences in facial affect synchrony during the FP, $F(1,72) = 3.12$, $p = .08$, $\eta_p^2 = .04$, observed power = .41, and RE, $F(1,69) = .02$, $p = .89$, $\eta_p^2 = .000$, observed power = .05.

Parent and Gender Differences in Physiological Synchrony for All Dyads

The following are results of analyses comparing all mother-infant and father-infant dyads, as well as same-gender and different-gender dyads on level of physiological synchrony when the infant was 6/9 months of age. Mother-infant and father-infant dyads did not differ significantly in physiological synchrony levels during the FP, $F(1,57) = .02$, $p = .88$, $\eta_p^2 = .000$, observed power = .05, while controlling for household income and child age. When controlling for child gender and paternal age, results indicated fathers reached a higher level of heart rate synchrony with infants during the RE than did mothers, $F(1,57) = 7.52$, $p = .01$, $\eta_p^2 = .12$, observed power = .77.

There were no significant differences in level of physiological synchrony for mother-infant dyads of the same gender versus those of a different gender during the FP (controlling for child age), $F(1,71) = .05$, $p = .83$, $\eta_p^2 = .001$, observed power = .06. However, during the RE episode, mother-daughter dyads had a greater degree of synchrony than did mother-son dyads, $F(1,70) = 5.12$, $p = .03$, $\eta_p^2 = .07$, observed power = .61. Father-son and father-daughter dyads had similar levels of synchrony during the FP episode when household income was controlled for, $F(1,65) = .76$, $p = .39$, $\eta_p^2 = .01$, observed power = .14, and during the RE when paternal age was included as a covariate, $F(1,67) = .04$, $p = .83$, $\eta_p^2 = .001$, observed power = .06.

Predictors of Parent-Infant Synchrony at 6/9 Months

Mother-infant affect and physiological synchrony were examined using separate multiple regression models for each episode and type of synchrony. At 6/9 months, maternal depressive symptoms and self-reported relationship satisfaction were not significantly associated with mother-infant facial affect synchrony during the FP episode when controlling for household income and child race, nor during the RE with no covariates included (see Table 4). Furthermore, depressive symptoms and relationship satisfaction were not significant predictors of mother-infant physiological synchrony for either episode (see Table 5 for included covariates and model statistics).

Table 4

Results of Multiple Regression Models for Facial Affect Synchrony- Mother

	Freeplay (R^2 = .15)		Reunion (R^2 = .003)	
Variable	*beta*	*p*	*beta*	*p*
Intercept	**.18**	**.01**	**.24**	**.002**
Mother Depressive Symptoms	-.000	.99	-.001	.64
Mother Relationship Satisfaction	-.000	.84	.000	.89
Household Income	.01	.07	--	--
Child Race	**-.06**	**.03**	--	--

Note. Bolded values are significant at $p < .05$.

Table 5

Results of Multiple Regression Models for Physiological Synchrony- Mother

	Freeplay (R^2 = .08)		Reunion (R^2 = .07)	
Variable	*beta*	*p*	*beta*	*p*
Intercept	**.26**	**.01**	**.25**	**.000**
Mother Depressive Symptoms	-.001	.54	.000	.95
Mother Relationship Satisfaction	.001	.26	.000	.36
Child Age (continuous)	**-.21**	**.04**	--	--
Child Gender	--	--	**.03**	**.04**

Note. Bolded values are significant at $p < .05$.

While controlling for child age, father depressive symptoms, relationship satisfaction, father involvement, and fathering attitudes were not significant predictors of father-infant facial affect synchrony at 6/9 months during the FP episode of the SFP (see Table 6). Depressive symptoms and father involvement reported by the father were also not associated with father-infant facial affect synchrony during the RE episode. The same analysis showed that increased father-reported relationship satisfaction marginally predicted decreases in father-infant facial affect synchrony during the RE episode, $b = -.001$, $p = .06$. Additionally, more positive fathering attitudes were significantly associated with increased infant-father facial affect synchrony during the RE episode, $b = .003$, $p = .03$. The father's level of depressive symptoms, relationship satisfaction, father involvement and attitudes towards fathering were non-significant predictors of physiological synchrony for both episodes with respective covariates (Table 7).

Table 6

Results of Multiple Regression Models for Facial Affect Synchrony- Father

	Freeplay (R^2 = .06)		Reunion (R^2 = .13)	
Variable	*beta*	*p*	*beta*	*p*
Intercept	.08	.44	.17	.10
Father Depressive Symptoms	.001	.58	.000	.77
Father Relationship Satisfaction	.000	.31	-.001	.06†
Father Involvement	-.01	.29	-.004	.65
Fathering Attitudes	.002	.31	**.003**	**.03**
Child Age (6 or 9 months)	.02	.41	-.02	.30

Note. Bolded values are significant at $p < .05$, †marginal at $p < .10$.

Table 7

Results of Multiple Regression Models for Physiological Synchrony- Father

	Freeplay (R^2 = .09)		Reunion (R^2 = .10)	
Variable	*beta*	*p*	*beta*	*p*
Intercept	.22	.18	**.54**	**.001**
Father Depressive Symptoms	.001	.82	-.002	.44
Father Relationship Satisfaction	.000	.45	-.001	.41
Father Involvement	.000	.98	.001	.92
Fathering Attitudes	.001	.49	-.001	.52
Household Income	-.02	.08	--	--
Child Age (6 or 9 months)	-.04	.25	.04	.25
Father Age	--	--	-.004	.08

Note. Bolded values are significant at $p < .05$.

Predictors of Preschool Emotion Regulation

The following are results of covariate analyses for the effects of demographic variables on the outcome of child self-regulation at 3 years of age. Child gender, child race, parent race, parent education, and household income were not significantly related to preschool child emotion regulation scores and therefore, no covariates were included in subsequent analyses. However, child age (dichotomous) was included when father involvement was a predictor, as it was previously shown to be related.

For mothers, dyads had levels of mother-infant facial affect synchrony unrelated to the child's emotion regulation at age 3 for both the FP episode, $b = .19$ ($SE = .81$), $p = .82$, and RE episode, $b = .33$ ($SE = .63$), $p = .60$. Father-infant facial affect synchrony during the FP, $b = -.06$ ($SE = .74$), $p = .94$, was not associated with a composite of the child's expression of anger and frustration during an emotion regulation task at 3 years of age. The synchrony of the dyad in the RE, $b = .41$ ($SE = .75$), $p = .59$, was also a non-significant predictor.

Physiological synchrony for both mother-infant FP, $b = .22$ ($SE = .57$), $p = .71$, and RE, $b = -.60$ ($SE = .87$), $p = .50$, did not significantly predict child emotion regulation at age 3. The same was true for the father-infant FP, $b = -.37$ ($SE = .51$), $p = .47$ and RE episode of the SFP at 6/9 months, $b = .84$ ($SE = .50$), $p = .10$. Finally, while controlling for age at the 6/9-month visit, father involvement, $b = -.01$ ($SE = .05$), $p = .79$, and fathering attitudes when the infant was 6/9 months old, $b = -.01$ ($SE = .01$), $p = .17$, were not significantly associated with the child composite emotion regulation scores at age 3.

Covariate Analyses for Synchronous Dyads

The following sets of analyses included only the subset of dyads from the study sample that had a significant degree of synchrony according to the dyad CCF plot. Degree of facial affect synchrony during the father-infant RE episode for only synchronous dyads differed by age at first visit- 6 or 9 months, $F(1,46) = 5.37$, $p = .03$, and 6-month-olds showed a greater degree of father-infant facial affect synchrony than 9-month-olds. Household income was also associated with level of heart rate synchrony for infant-father dyads during FP, $F(3,51) = 3.40$, $p = .03$. Otherwise, there were no differences by child age, order of which parents completed the SFP, child gender, child race, household income, parent race, or parent education, for infant-parent synchrony levels in any of the episodes with facial affect or heart rate synchrony for only synchronous dyads, *p*s > .05.

Parent and Gender Differences in Facial Affect Synchrony for Synchronous-Only Dyads

The same comparison of mother-infant and father-infant synchronous-only dyads was made for the FP and RE episodes, as well as for facial affect and physiological synchrony. There was no significant difference in facial affect between dyads containing the mother and father during the FP episode, $F(1, 31) = .28$, $p = .60$, $\eta_p^2 = .01$, observed power = .08. For facial affect synchrony, there was a significant interaction between child age (6 or 9 months) and parent with whom the RE episode was completed, $F(1,19) = 4.47$, $p = .05$, $\eta_p^2 = .19$, observed power = .52. Specifically, 9-month-olds were more synchronous with their mothers than fathers, whereas 6-month-olds' synchrony did not differ significantly between the two parents.

For mothers, same-gender and different-gender dyads had similar levels of facial affect synchrony in both the FP episode, $F(1, 59) = .16$, $p = .69$, $\eta_p^2 = .003$, observed power = .07., and the RE episode of the SFP, $F(1, 42) = .07$, $p = .80$, $\eta_p^2 = .002$, observed power = .06. Father-son dyads did not differ in facial affect synchrony during the FP episode, $F(1, 49) = .99$, $p = .33$, $\eta_p^2 = .02$, observed power = .16, or the RE episode, $F(1, 44) = .67$, $p = .42$, $\eta_p^2 = .02$, observed power = .13.

Parent and Gender Differences in Physiological Synchrony for Synchronous-Only Dyads

Mother- and father-infant dyads were also tested for differences in physiological (i.e., heart rate) synchrony for each the FP and RE episodes of the SFP. Controlling for household income as a between-subjects variable, there was no significant difference in heart rate synchrony during the FP episode between mother-infant and father-infant dyads, $F(1, 27) = .2.54$, $p = .12$, $\eta_p^2 = .09$, observed power = .34. The same was true for physiological synchrony during the RE episode with no covariates, $F(1, 29) = 1.94$, $p = .17$, $\eta_p^2 = .06$, observed power = .27.

Finally, synchronous-only dyads were examined to determine if parent-infant dyads differed when the parent and infant matched in gender, compared to when they did not. Mother-son and mother-daughter dyads did not differ in heart rate synchrony during the FP, $F(1, 46) = .94$, $p = .34$, $\eta_p^2 = .02$, observed power = .16, or RE episode, $F(1, 42) = 2.42$, $p = .13$, $\eta_p^2 = .05$, observed power = .33. Father-son and father-daughter dyads were similar in levels of synchrony during the FP episode, $F(1, 48) = .28$, $p = .60$, $\eta_p^2 = .01$, observed power = .08, even when controlling for household income level. For the RE episode, with no covariates, they also did not differ in degree of physiological synchrony, $F(1, 47) = .000$, $p = .99$, $\eta_p^2 = .000$, observed power = .05.

Predictors of Parent-Infant Synchrony for Synchronous-Only Dyads

No significant predictors of facial affect synchrony or physiological synchrony were found when examining only synchronous dyads from the FP and RE. For mothers, potential predictors were maternal depressive symptoms and relationship satisfaction (see Tables 8 and 9). For fathers, depressive symptoms, relationship satisfaction, level of father involvement, and positive fathering attitudes were included as possible predictors (see Tables 10 and 11 for results). Child age was included as a covariate in father analyses, since it was previously shown to be associated with father involvement.

Table 8

Results of Multiple Regression Models for Facial Affect Synchrony (Synchronous Only)- Mother

	Freeplay (R^2 = .02)		Reunion (R^2 = .02)	
Variable	*beta*	*p*	*beta*	*p*
Intercept	**.24**	**.000**	**.24**	**.01**
Mother Depressive Symptoms	.001	.30	-.002	.39
Mother Relationship Satisfaction	.000	.91	.000	.77

Note. Bolded values are significant at $p < .05$.

Table 9

Results of Multiple Regressions for Physiological Synchrony (Synchronous Only)- Mother

	Freeplay (R^2 = .02)		Reunion (R^2 = .07)	
Variable	*Beta*	*p*	*beta*	*p*
Intercept	**.19**	**.03**	**.24**	**.000**
Mother Depressive Symptoms	.001	.79	-.002	.15
Mother Relationship Satisfaction	.000	.42	.000	.62

Note. Bolded values are significant at $p < .05$.

Table 10

Results of Multiple Regression Models for Facial Affect Synchrony (Synchronous Only)- Father

	Freeplay (R^2 = .02)		Reunion (R^2 = .16)	
Variable	*Beta*	*p*	*beta*	*p*
Intercept	.22	.07	.18	.12
Father Depressive Symptoms	.000	.90	.000	.87
Father Relationship Satisfaction	.000	.58	.000	.51
Father Involvement	.002	.84	-.01	.61
Fathering Attitudes	.001	.60	.002	.16
Child Age (6 or 9 months)	-.004	.88	**-.05**	**.04**

Note. Bolded values are significant at $p < .05$.

Table 11

Results of Multiple Regression Models for Physiological Synchrony (Synchronous Only)- Father

	Freeplay (R^2 = .09)		Reunion (R^2 = .09)	
Variable	*Beta*	*p*	*beta*	*p*
Intercept	.28	.12	**.54**	**.004**
Father Depressive Symptoms	.002	.53	.000	.87
Father Relationship Satisfaction	.001	.12	.000	.93
Father Involvement	-.01	.48	-.001	.93
Fathering Attitudes	-.001	.69	-.004	.11
Household Income	-.02	.18	--	--
Child Age (6 or 9 months)	-.02	.52	.05	.21

Note. Bolded values are significant at $p < .05$.

Predictors of Preschool Emotion Regulation (Only Synchronous Dyads)

As with the analyses for all dyads, the analyses for only significantly synchronous dyads from the 6/9-month visit did not include any covariates, given that the outcome of child emotion regulation scores did not differ by any of the tested demographic variables, *p*s > .05. Again, the dichotomous child age variable was related to father involvement and therefore included when father involvement was included. Mother-infant facial affect synchrony was unassociated with emotion regulation at 3 years for both the FP episode, b = .66 (SE = 1.10), p = .55, and reunion episode, b = -.14 (SE = .84), p = .87. Levels of father-infant facial affect synchrony for the FP, b = .05 (SE = 1.09), p = .96, and RE episodes with the father, b = -.09 (SE = 1.11), p = .94, were not predictive of the child emotion regulation scores at the age of 3. Furthermore, physiological synchrony for mother-infant FP, b = .15 (SE = .77), p = .85, and RE, b = -1.43 (SE = 1.40), p = .32, were not significant predictors of later child emotion regulation when only synchronous dyads were included. Also found to be non-significant predictors of child emotion regulation at 3 years of age were the degree of father-infant heart rate synchrony during the FP, b = -.17 (SE =

.63), *p* = .80 and the RE episode of the SFP at 6/9 months, *b* = .69 (*SE* = .62), *p* = .27. Additional father-specific predictors tested from the 6/9-month visit were father involvement and fathering attitudes. Both level of father involvement, *b* = -.01 (*SE* = .05), *p* = .79, and fathering attitudes when the infant was 6/9 months old, *b* = -.01 (*SE* = .01), *p* = .17, were found to be non-significant predictors of 3-year-old emotion regulation, while controlling for child age at the first visit.

Predictors of Preschool Emotion Regulation (Synchronous vs. Non-Synchronous)

A final set of analyses in which those who reached a significant level of facial affect synchrony with the parent were compared to those who did not in level of emotion regulation demonstrated at 3 years of age. Those mother-infant dyads with a non-significant degree of facial affect synchrony were statistically equal in emotion regulation at 3 years to those with significant facial affect synchrony during one episode, $F(1,47) = .35$, $p = .56$, or both episodes, $F(1,34) = .01$, $p = .91$. Similarly, father-infant dyads who achieved significant levels of facial affect synchrony during one episode, $F(1,43) = .44$, $p = .51$, or both episodes, $F(1,34) = .20$, $p = .66$, did not differ significantly in emotion regulation at 3 years of age compared to those who did not reach a significant level of synchrony with the parent in either SFP episode at the 6/9-month visit.

Discussion

Overall, the aims of the current study were to reproduce previous research findings that mother- and father-infant dyads could show equal degrees of affective synchrony, and to extend that to include physiological synchrony. Other aims were to examine and describe physiological regulatory responses of parents and infants during the SFP. Finally, the researcher sought to explore potential predictors of parent-infant synchrony at 6/9-months and child emotion regulation at 3 years of age, including parent depressive symptoms, relationship satisfaction, father involvement, and fathering attitudes. While the current study did not provide support for all of the researcher's hypotheses, results did replicate and extend multiple findings from previous studies.

Description of Parent and Infant RSA

One goal of the study was to examine and describe changes in RSA, an indicator of emotion regulation, from episode to episode of the SFP for parents and infants. For mothers, this was an attempt to replicate previous research findings and for fathers it was to provide a description of fathers' physiological response to the SFP for the first time. As in previous work, mothers showed a significant decrease in RSA from the SF to RE (Ham & Tronick, 2006; Moore et al., 2009). Social engagement or facilitation of engagement with an infant, which involves meeting changing demands of the environment, is thought to be associated with decreases in RSA in adults (Moore et al., 2009). This may explain why mothers in the present study showed RSA decreases, since they were moving from a state of non-engagement with the infant to a state of re-engagement with the infant from the SF to the RE. Also consistent with past research, infants in the current study showed a significant decrease in RSA from the FP to the SF (Ham & Tronick, 2006; Moore & Calkins, 2004). A decrease in RSA in infants and young children is thought to be associated with increased attempts at emotion regulation, which is what might be inferred for infants during the stressful SF episode (Buss et al., 2005).

Neither fathers nor infants showed significant changes in RSA during the father-infant SFP. Only one known study has measured RSA levels of fathers of typically-developing infants during the SFP and that study did not report changes (or lack thereof) in RSA for the placebo group, as the researchers' primary goal was to compare RSA levels of a placebo group and a group that received oxytocin administration prior to father-infant interactions during the SFP (Weisman et al., 2012). Therefore, there was no prior basis with which to compare fathers' and infants' RSA responses during the SFP. However, the lack of significant changes in RSA seems maladaptive when taken with the knowledge that decreases in RSA appear to be adaptive when faced with a stressful situation, such as a social stressor (Moore et al., 2009). The SFP is somewhat stressful for infants, regardless of whether they complete it with their mothers or their fathers (Braungart-Rieker et al., 1998). It is, therefore, odd that during father-infant interactions neither showed participant exhibited significant changes in RSA across the SFP. The lack of changes in father and infant RSA may suggest a lack of emotion regulation processes. It is also possible that fathers showed no changes because they were not physiologically preparing for social engagement and helping the infants facilitate their own emotion regulation during the stressful RE episode. These are possible explanations that have been provided for mothers' decreasing RSA values between the SF and RE episodes and could, conversely, explain why fathers did not show similar physiological changes (Moore et al., 2009).

Though the overall RSA responses of mothers and infants from the current and past studies generally make sense in the context of the SFP, average RSA is obviously too crude a measure with which to examine actual parent-infant synchrony because it calculated from RSA values averaged across 60 s intervals. Previous research found that mothers' and infants' IBIs changed rapidly to achieve physiological synchrony, changing at even split-second lags to match one another (Feldman et al., 2011). Therefore, second-by-second heart rate likely provides a more precise measure of physiological responses during the SFP and a better way to examine parent-infant synchrony, which was thus used in the current study.

Parent and Gender Differences in Facial Affect and Physiological Synchrony

One major goal of the current research was to investigate whether differences exist between mother-infant and father-infant dyads in facial affect and physiological synchrony. Findings from the comparison of mothers' and father's synchrony levels with infants partially supported the researcher's hypotheses that synchrony would not differ by parent but would be greater in same-gender dyads. As had been found previously (Feldman, 2003), there were no overall differences between mother-infant and father-infant dyads in facial affect synchrony when all dyads were examined. From a developmental standpoint, these findings are positive because they suggest that infants are getting equally sensitive or synchronous interactions with both of their parents. More synchronous parent-infant interactions have been found to lead to more positive outcomes, such as increased self-control when the child is 2 years of age (Feldman et al., 1999).

Another aim of the current research was to elucidate mixed findings about differences in affective synchrony levels when parents and infants were the same gender, as opposed to when they were not. Unlike previous findings (Feldman, 2003; Tronick & Cohn, 1989), however, the level of affective synchrony did not differ for same and different gender parent-infant dyads. This could be because of the different measures used to examine affective synchrony. Previous studies primarily used the Monadic phases as a measure of affective synchrony, whereas the current study focused on facial affect alone.

The current study extended previous research by examining not only mother-infant heart rate, or physiological synchrony, but also by comparing it to father-infant synchrony. Interestingly, when all dyads were examined, fathers showed a higher degree of physiological synchrony with infants than mothers did during the RE episode. This finding could potentially be explained somewhat by the pattern of RSA shown by fathers and infants in the current study. During the SFP, both fathers and their infants showed non-significant changes in RSA. Previous research has shown that infants typically increase RSA levels when moving from the FP to SF episodes of the SFP in likely attempts to regulate their own emotions and deal with the stress of social disengagement (Moore et al., 2009). On the other hand, mothers typically decrease RSA from the SF to the RE episodes in likely attempts to re-engage socially and help infants cope with their negative emotions (Moore et al., 2009). RSA tends to be inversely related to heart rate and mothers and their infants tend to show inverse changes in RSA across the SFP. The fact that fathers are not showing similar changes in RSA to mothers suggests they may be more synchronous than mothers with infants in heart rate during the relatively stressful RE episode. However, this may be a case in which greater parent-infant physiological synchrony is not adaptive.

This study also extended existing research by investigating whether there were same-gender and different-gender dyad differences in physiological synchrony. There were no heart rate synchrony differences between same-gender and different-gender dyads for mothers or fathers in the FP episode. However, mother-daughter dyads showed higher levels of heart rate synchrony than mother-son dyads during the RE. To the knowledge of the researcher, this research question had not been examined previously using heart rate or any second-by-second physiological indices of synchrony. There is no research to suggest differences would exist based on child gender in physiological parent-infant synchrony, other than a study which suggested a high degree of concordance between physiological and affective synchrony (Feldman et al., 2011) in combination with findings that affective synchrony differed in same-gender versus different-gender dyads (Feldman, 2003). However, a possible explanation for the greater physiological synchrony in mother-daughter dyads during the RE episode lies in daughters' responses to their mothers. The RE is considered a somewhat stressful episode for infants, in which they display more negative affect and distress than in the FP episode. Therefore, mothers are likely trying to vocally console their infants in many cases and previous research has suggested that infant daughters are more responsive to mothers' vocalizations alone than infant sons (Gunnar & Donahue, 1980). This difference in synchrony during a stressful situation may be one avenue through which sons and daughters develop differently in both social and emotional aspects.

Findings were generally the same or became statistically non-significant when only those dyads who reached significant facial affect synchrony levels according to the CCF plots were included in analyses. The one exception was that 9-month-old infants showed greater facial affect synchrony with their fathers than mothers during the RE, but at 6 months mother-infant and father-infant dyads were more similar. When only dyads that reached significant levels of heart rate synchrony were included, there were no differences by parent or for same-gender dyads. These findings were most likely due to the small sample sizes in the current study when only synchronous dyads were included, particularly for the RE episode. However, the researcher ran two sets of analyses, one which only included the synchronous dyads, since some previous research had excluded dyads with no significant synchrony spikes on the CCF (Feldman at el., 1999).

Predictors of Parent-Infant Synchrony at 6/9 Months

Several possible predictors of parent-infant facial affect and heart rate synchrony were tested, including depressive symptoms of both parents, relationship satisfaction reported by each parent, father involvement, and fathering attitudes. Contrary to the researcher's hypothesis, maternal depressive symptoms were not associated with facial affect synchrony during either tested episode of the SFP. Though it was consistent with the researcher's hypothesis, fathers' depressive symptoms were also not related to father-infant synchrony levels. A possible explanation for these findings is that parents generally do not present negative facial expressions during face-to-face interactions with their infant, and the infrequent occasions on which parents do so may be an empathetic gesture directed at the infant (Aktar et al., 2017). This may be one reason the present results did not support the idea that parents differ in level of facial affect synchrony with their infants as parental depressive symptoms increase. However, another reason for this may be that the sample of study participants was relatively high functioning, with few parents meeting criteria for probable depressive symptoms. The lack of association between parents' psychopathology (i.e., probable depression) is positive in a developmental sense because it suggests that parents' mental health difficulties are not spilling over to impact parent-infant synchrony, and in turn, infants' later self-control (Feldman et al., 1999).

As was expected, maternal relationship satisfaction was not related to mother-infant facial affect synchrony. However, there was a marginal relationship between increased relationship satisfaction predicting decreased father-infant facial affect synchrony during the RE. This relationship was in the opposite direction of what was expected, given that research previously found greater paternal relationship satisfaction significantly predicted increased father-infant affective synchrony (Lundy, 2002). Previous research also provides a possible explanation for this, which is that out of all parent-child combinations of both genders, fathers with low levels of marital satisfaction showed the most negativity to their young daughters during interactions (Kerig, Cowan, & Cowan, 1993). If infants exhibited increased negative affect during the RE, as previous research suggests they would, then fathers in dissatisfying marriages may have been more negative towards their infants. This would potentially lead to increased father-infant facial affect synchrony due to an increase in negative facial expressions. However, this is another example of a time when increased synchrony may actually be maladaptive.

The idea that increased father involvement and more positive fathering attitudes would predict synchrony level was speculative, given that no known previous research had directly examined the relationship for those two factors. However, greater father involvement has been associated with increased paternal sensitivity during father-infant interactions and fathering attitudes have been related to father involvement (Beitel & Parke, 1998; Feldman, 2000). This was the basis for including them as potential predictors of synchrony, which is thought to be an indicator of sensitivity. They were also included because of the researcher's desire to examine more father-specific factors and how they related to synchrony level.

Father involvement was not associated with greater facial affect synchrony, though it was hypothesized to be related. Fathering attitudes or views on the importance of the father's role were not predictive of facial affect synchrony during the FP episode. However, aligned with the study hypotheses, more positive fathering attitudes predicted increased father-infant facial affect synchrony during the RE episode. It may be relatively easier for dyads to achieve synchrony during the FP episode, given that fewer dyads (both mother and father) achieved synchrony during the RE episode. Sensitive parenting is likely more difficult when faced with an upset infant following a stressful situation, as often occurs during the RE episode of the SFP. Therefore, more positive fathering attitudes may be especially important in determining the behavior of fathers during the RE episode and thus, which dyads have higher levels of synchrony. It is possible that fathering attitudes are more important than father involvement in predicting behavior during father-infant interactions, which is why father involvement did not predict increased synchrony. Additionally, increased father involvement may not translate to more synchrony because an increase in quantity is not the same as an increase in quality. Whereas, fathers who feel more positively about the father role may be more motivated to have high-quality (e.g., more synchronous) interactions with their infants. Past research suggests that a major contributor to fathers' behavior, such as stimulation during interactions with their infants was fathers' more highly valuing of the father role (Beitel & Parke, 1998).

Physiological synchrony during the SFP was not anticipated to differ significantly with increases in depressive symptoms for either mothers or fathers. Results from the current study supported this hypothesis. Maternal relationship satisfaction was also not a significant predictor of mother-infant heart rate synchrony, as was expected. Conversely, hypotheses suggested that paternal relationship satisfaction, father involvement, and father attitudes would all be significant predictors of greater physiological synchrony between fathers and infants. Findings suggested otherwise, as none of the aforementioned variables significantly predicted father-infant heart rate synchrony. When synchronous-only dyads were used in analyses, none of the mother or father predictors were significantly related to facial affect or physiological synchrony in either SFP episode. Because very few studies have examined predictors or outcomes of parent-infant second-by-second heart rate synchrony, the hypothesized predictions for physiology were primarily based on the research suggesting that physiological synchrony and affective synchrony were closely related and would therefore, likely have similar predictors (Feldman et al., 2011). However, given the findings from the current study, facial affect synchrony may not have as high a concordance with physiological synchrony as suggested by previous studies. Instead, physiological synchrony appears to be somewhat less affected by outside factors than affective synchrony, which provides further support for previous research that found no differences in physiological synchrony between dyads with depressed and non-depressed mothers (Field et al., 1989).

There are a few different possibilities that may explain the general lack of significant findings related to predictors of parent-infant synchrony. Unfortunately, many dyads that completed the SFP at the initial visit had data that were unable to be analyzed for synchrony level for various reasons, ranging from technical errors to data with excessive movement artifact, which was unable to be cleaned. A small number of additional dyads could not be analyzed for synchrony because the variability in the time series was too small for SAS to compute after the series had been differenced to achieve stationarity, a necessary condition for using time series analysis. This led many of the study analyses to be underpowered, as seen in the reported observed power statistics. Furthermore, infants are notoriously difficult to collect physiological data from and this study was no exception. A combination of these factors likely played a role in the loss of data, leading to the small number of significant findings where significant findings were anticipated (i.e., Type II error).

Further possible issues stem from the fact that the parent-infant interactions were observed during the SFP, which is a novel and emotionally arousing situation for many infants, and this may have impacted the level of synchrony. Some previous researchers (Feldman, 2003) have utilized 10 min free play sessions occurring in the home, which were unlikely to upset the infant. The location and length of that type of interaction may provide a more naturalistic interaction and be a better situation in which to observe parent-infant synchrony. While the researcher thought it would be more important for infant-parent dyads to be synchronous during such a stressful situation, it may also be more difficult to achieve synchrony under those stressful circumstances and may be less realistic for infants to experience those types of situations in daily life (except in specific cases, such as when the mother is depressed).

Across both parents and both episodes of the SFP, there were fewer dyads that achieved a statistically significant degree of facial affect or physiological synchrony during the RE episode than the FP episode. This is most likely because the RE is a more stress-inducing episode for infants than the FP episode, which is most like typical naturalistic parent-infant interactions. Thus, the RE was more likely to end early and the smaller number of synchronous dyads during the RE episode may be a product of the shorter length (of time) of many infant-parent reunions. The infants, who were often upset upon reunion, were watched for approximately 30 s once they became upset and if they had not yet calmed down, the episode ended. Therefore, many RE episodes were 30-45 s, whereas the majority of FP episodes lasted a full 120 s. This makes sense, given that previous studies found that infants cried more and showed greater fussiness during the RE episode of the SFP than in the FP or SF episodes (Weinberg & Tronick, 1996).

Predictors of Preschool Emotion Regulation

One of the primary aims of the current study was to examine possible predictors of emotion regulation ability in preschool-aged children. Specifically, the researcher sought to determine whether parent-infant synchrony, father involvement, or fathering attitudes were associated with later child emotion regulation. The researcher hypothesized that a greater degree of facial affect or physiological synchrony for mother-infant and father-infant dyads would be associated with increased emotion regulation ability at 3 years of age. Higher levels of father involvement and positive fathering attitudes were also thought to be likely predictors of better child emotion regulation at 3 years of age.

Mother-infant and father-infant facial affect and physiological synchrony were not associated with later child emotion regulation for either episode of the SFP. Nor were other tested predictors. When synchronous-only dyads were examined, none of the possible predictors had significant relationships with later child emotion regulation ability. The results of comparing dyads who reached synchrony during one or both of the FP and RE episodes of the SFP and those who did not confirmed the lack of differences in emotion regulation in the current sample. This suggests that reaching a significant level of dyadic synchrony during early infancy does not mean children will demonstrate better emotion regulation at 3 years of age. There are several possible explanations for this. First, this could indicate that a greater level of synchrony is not always a good thing, which is why it wouldn't necessarily lead to increases in a positive child outcome such as better child emotion regulation ability. This would be consistent with findings of some past research showing maladaptive associations with mother-infant synchrony (e.g., Beebe et al., 2008; Lotzin et al., 2016), such as the finding that more depressed mothers exhibited greater levels of facial affect synchrony with their infants.

The lack of a significant predictive relationships with emotion regulation could also be explained by the large amount of elapsed time between visits, which was approximately 2.5 years. The only study to date which has directly examined the relationship between parent-infant synchrony and child regulatory ability had about one year less of a time gap between measurement of parent-infant synchrony and child self-control than did the current study (Feldman et al., 1999). A further explanation is that the participating families in this study were all relatively high functioning and had high levels of both parent-infant synchrony and children with high emotion regulation ability for their age. This may be evidenced by the fact that the mean levels of synchrony in the current sample (indexed as the largest CCF on the CCF plot) were higher than those found in previous research (e.g., Feldman, 2003).

One of the interesting pieces about this study is that there were no differences found for emotion regulation at 3 years of age based on child gender. This was not a primary research question in the current study, but previous research suggests that boys are worse at emotion regulation than girls. For instance, using a combination of other tasks from the Preschool Lab-TAB and the same Lock Box task (also taken from the Lab-TAB), researchers found that 4.5-year-old boys exhibited greater anger, but similar levels of sadness as 4.5-year-old girls (Gagne, Van Hulle, Aksan, Essex, & Goldsmith, 2011). However, this study did not find gender differences in the composite self-regulation score, which included both anger and sadness during the Lock Box task. That being said, there is also a possibility that there are other studies with null findings of gender differences in children's emotion regulation that are unpublished. Studies with null findings are much less likely to be published in the social sciences (Franco, Malhotra, & Simonovits, 2014), which is likely contributing to what is deemed the scientific replication crisis. Besides assuming there are no existing gender differences between emotion regulation abilities in the general population, another possible explanation is that differential expression of emotions by gender is not yet detectable at 3 years of age. Three-year-olds are notoriously and universally poor at performing in most developmental areas, but they tend to allow wishful thinking to influence their judgments (Bernard, Clement, & Mercier, 2016) and even slightly older preschool-aged children tend to have an overinflated sense of confidence in certain areas (Lipko, Dunlosky, & Merriman, 2009). Since emotion regulation is a skill that is only emerging at 3 years of age, participants may have performed poorly regardless of their gender. Gender norm socialization by parents and other caregivers begins very early, but there may not be obvious differences at such an early age.

Limitations and Future Directions

The current study had some limitations, which will be discussed, with suggestions and implications for related future research. Primarily, readers should be cautioned that the convenience sample of participants from this research consisted mostly of highly educated, middle-class families and thus, the generalizability of findings may be limited to those families of similar circumstances. The demographics of the sample also suggest it is a high-functioning group of participants, within which very few families had demographic-related risk factors that might impact emotion regulation, such as low household income. The particular sample may also have contributed to null findings with regard to preschool emotion regulation. It may also have a restricted range of parent-infant synchrony than might be seen in more diverse samples. This could explain why other studies had some findings which were different from those in the current study. Further research with a more diverse, representative sample is necessary to extend these findings to families from a wider array of socioeconomic and other backgrounds. In order to obtain a more diverse sample, future researchers may use recruitment methods that reach a wider audience, such as focusing efforts on public hospitals, school districts, or other public service providers.

Another limitation of the current study is that it differed from a portion of the other studies in the coding system used to determine level of affective synchrony. Previous researchers used various coding systems, with one of the most commonly used being Tronick and colleagues' (1980) monadic phases coding. The coding used for this project, which requires similar facial expressions of parent and infant to indicate synchrony, may be a more conservative measure of parent-infant behavioral synchrony. For instance, it may be unusual for a parent to show an extremely negative facial expression to their infant when interacting. However, parents' behavior could still be related to that of infants in that they both move from a more positive to more negative affective state. While it is arguably important to observe individual components of affect synchrony in isolation, future research may consider coding multiple dimensions of behavior independently and examining synchrony in each modality. For instance, researchers may behaviorally code and examine facial affect, gaze, body positioning, and touch for levels of parent-infant synchrony separately.

The current study had an unfortunately high attrition rate due to the long period (i.e., 2.5 years) between the initial and final visits of the study. Slightly more than 35% of participants who began the study did not return for the visit with the child was 3 years of age. Approximately 7% were not invited back due to not meeting criteria of participating in at least one of the two intermediate visits. There were various reasons for the remainder of lost participants, such as multiple families that moved out of state and many being unable to be contacted. However, the high attrition rate affected the statistical power of analyses and ability to detect any effects that may have otherwise been present. Future research may address this by maintaining frequent contact with participants and reminding them of their important role in the research project. Additionally, it may be helpful to recruit a larger number of families initially, to counter the attrition that will inevitably occur.

The current study and additional research into parent-infant synchrony could have important implications for the field of child psychopathology. Previous research has hinted at the possible utility of increased knowledge about parent-infant synchrony in understanding development of child psychopathology (Feldman, 2007a). Findings from one previous study indicated that children with higher levels of autism spectrum disorder (ASD) symptomatology had decreased physiological synchrony with their parents during interactions (Baker et al., 2015). Abnormalities in the development of parent-infant synchrony may, thus, be one potential early indicator of atypical child development. Parent-infant synchrony may eventually be so well understood that if it were measured in a uniform way, it could assist with diagnostic assessment or serve as a known risk factor to indicate families who might benefit most from family interventions. Specifically, such interventions might target sensitivity during parent-infant interactions to promote optimal child development. However, this will require much additional research, especially in the case of father-infant synchrony.

Conclusion

Findings from the current study add to the existing body of literature surrounding parent-infant synchrony, particularly where fathers are concerned. However, this study also highlights the lack of consensus in results from existing parent-infant synchrony work and the need for continued research to examine both predictors and outcomes of parent-infant synchrony across multiple modalities. While this study did not find associations between parent-infant synchrony and emotion regulation, past studies have found that synchrony is important for the development of overall self-control, which is a precursor to later self-regulation (Feldman et al., 1999; Kopp, 1982).

The results of the current study provided the first known description of second-by-second heart rate synchrony of fathers and their infants during multiple episodes of the SFP. This is the first known study to simultaneously examine second-by-second heart rate in conjunction with second-by-second affective states in father-infant dyads. This is an important contribution of the current study to the field, as previous theory suggests it is important to examine both physiological and behavioral processes simultaneously to better understand the dynamic processes of social interactions between infants and caregivers (Feldman, 2012). Given that the findings in the current study varied by modality of synchrony (i.e., heart rate vs. facial affect), this study also provides support for the idea from bio-behavioral synchrony theory (Feldman, 2012) that there is a complex interplay between ongoing physiological processes and behavior which leads to synchronous interactions and the development of dyad-specific infant-caregiver bonds.

The current study confirmed that mothers and fathers were able to have similarly synchronous or sensitive interactions with their 6/9-month-old infants, as measured through parent-infant facial affect synchrony. However, findings from the current study, which sometimes differed between mothers and fathers (e.g., changes in RSA during the SFP), also suggest that mothers and fathers may offer different interaction experiences to infants. Mothers and fathers may, therefore, play important but distinct roles in their child's socioemotional development. Mothers have historically been seen as the primary and most important figure in child development, but these collective findings suggest that fathers are, at least, equally important.

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ABSTRACT

FACIAL AFFECT AND PHYSIOLOGICAL SYNCHRONY DURING PARENT-INFANT INTERACTIONS AND INFLUENCES ON LATER DEVELOPMENTAL OUTCOMES

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Dyadic synchrony is the degree of coordination of behavior or states of partners in social interaction. Synchrony between parents and their infants is thought to be important for the development of self-regulatory abilities. The purpose of the current study was to examine factors associated with parent-infant synchrony when infants were 6-9 months old and outcomes of parent-infant dyadic synchrony when the child was 3 years of age. Facial affect synchrony and physiological synchrony of mothers and fathers with their infants was compared during the free play (FP) and reunion (RE) episodes of the Still Face Procedure (SFP). Depressive symptoms, relationship satisfaction, father involvement, and fathering attitudes were examined as potential predictors of parent-infant synchrony. Additionally, dyadic synchrony and father-specific factors were examined as potential predictors of later child emotion regulation. Results indicated that mothers and fathers were equally synchronous with infants in facial affect synchrony, but some differences were found for physiological synchrony. Fathering attitudes predicted father-infant facial affect synchrony during the relatively stressful RE episode of the SFP. No significant predictors of later child emotion regulation were identified. Further research is necessary to clarify mixed findings about predictors and outcomes of synchrony from this and other studies. Implications for future research and interventions are discussed.