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Mother–Infant Affect Synchrony as an Antecedent of the Emergence of Self-Control

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This study examined relations between mother–infant affect synchrony and the emergence of children's self-control. Mother–infant face-to-face play and infant difficult temperament were examined at 3 and 9 months. Maternal and infant affective states at play were coded in 0.25-s frames, and synchrony was computed with cross-correlation functions. Self-control, verbal IQ, and maternal warm discipline were assessed at 2 years. Maternal synchrony with infant affect at 3 months (infant-leads–mother-follows relation) and mutual synchrony at 9 months (cross-dependence between maternal and infant affect) were each related to self-control at 2 years when temperament, IQ, and maternal style were partialed. Infant temperament moderated the relations of synchrony and self-control, and closer associations were found between mutual synchrony and self-control for difficult infants. Shorter lags to maternal synchrony at 3 months were independently related to self-control. The mutual regulation of affect in infancy, as moderated by temperament, is proposed as an important contributor to the emergence of self-regulation.

The renewed interest in the origins of socialization in recent years has led to the emergence of a new empirical focus: the study of self-regulatory mechanisms as both antecedents and moderators of socialization processes. Various expressions of children's self-regulatory abilities have been examined in relation to children's compliance to parental requests, internalization of parental rules, and socialization to norms of conduct (Eisenberg & Fabes, 1992; Kochanska, Murray, & Coy, 1997). The revisiting of early social development has influenced research in two important directions. First, the early preverbal precursors of self-regulation, particularly aspects of the infant–caretaker mutual regulatory system, have been proposed to play an important role in the process of socialization (Emde, 1992; Kochanska, 1994; Tronick, 1989). Second, temperamental factors, especially those related to the regulation of arousal, fear, or negative emotionality, are being integrated into models of socialization (Kagan, 1987; Kochanska, 1991, 1997; Rothbart, Ahadi, & Hershey, 1994).

Of the several parameters that define the mother–infant mutual regulatory system, the temporal coordination of affect during parent–child interaction has received theoretical attention as a possible factor in the development of self-regulation. Models of psychobiological regulation (Hoffer, 1994; Schore, 1994), emotion regulation (Tronick, 1989), self-regulation (Kopp, 1982), dynamic systems coregulation (Fogel, 1993), socialization (Maccoby, 1992), and morality (Emde, Biringen, Clyman, & Oppenheim, 1991) suggest that self-regulation develops in the context of mutual regulatory parent–infant systems and that the coordination of affective expression during face-to-face interactions facilitates the transition from mutual regulation to self-regulation. Face-to-face interactions, emerging at approximately 2 months of age, are highly arousing, affect-laden, short interpersonal events that expose infants to high levels of cognitive and social information. To regulate the high positive arousal, mothers and infants have been shown to synchronize the intensity of their affective behavior within lags of split seconds (Cohn & Tronick, 1988; Lester, Hoffman, & Brazelton, 1985). Face-to-face synchrony affords infants their first opportunity to practice interpersonal coordination of biological rhythms, to experience the mutual regulation of positive arousal, and to build the lead–lag structure of adult communication (Beebe & Gerstman, 1980; Jasnow & Feldstein, 1986; Stern & Gibbon, 1978). Synchrony therefore provides the first context for the integration of self-regulation and social fittedness, the two dispositions theorized to underlie moral development (Emde, 1992). Despite the theoretical significance ascribed to affect synchrony, however, little longitudinal research has related the mutual regulation of affect during face-to-face interactions to the emergence of self-regulation. Thus, the first goal of this study was to examine links between mother–infant affect synchrony during the infant's 1st year and self-control at 2 years. The second goal was to examine the contribution of both temperament and synchrony to the development of self-control.

In her model of the antecedents of self-regulation, Kopp (1982) delineated a developmental path from "coordinated interactions" at 3 months to self-regulation at 3 years. The model organized the three constructs often used in relation to socialization—control, self-control, and self-regulation—in a developmental sequence. Self-control, a milestone typically attained by the age of 2 years, is defined as "behavior according to social expectations in the absence of external monitors" (Kopp, 1982, p. 202) and marks the

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first expression of internalized socialization. Self-control differs from self-regulation "in degree, not in kind" (Kopp, 1982, p. 207); both concepts share an internalized dimension. The two constructs, however, differ from the previous stage of control, which implies behavioral inhibition rather than mental internalization. Self-control is indexed by two types of behaviors: the child's compliance to parental commands and ability to delay acts on request, behaviors that reflect the "dos and don'ts" of early moral development (Emde et al., 1991). The emergence of self-control coincides with a global developmental transition: the onset of representational thought (Piaget, 1952), the shift from nurturance to discipline in parent–child relations (Gralinski & Kopp, 1993), and the appearance of obvious discomfort in the face of minor mishaps (Kagan, 1984). These developments mark the 2nd year as a period of shift from external modes of regulation to internal forms of control and from sensorimotor regulatory mechanisms to symbolic ones.

Synchrony is the process by which a series of events follows another series of events at a stable time lag (Rosenfeld, 1981). This definition applies to synchrony in dynamic systems and considers time an indispensable parameter of the synchronizing process. Synchrony in dynamic systems, such as social systems, is a complex, emergent, and indeterminate process that reflects the degree to which interactants integrate into the flow of behavior the ongoing responses of their partner and the changing inputs of the environment (Fogel & Branco, 1997). Applying nonlinear models to face-to-face interactions, researchers have detected two organizational principles underlying the first social dialogue: cyclicity, the autocorrelated component in mother and infant behavior, and synchrony, the cross dependence between mother and infant affect (Cohn & Tronick, 1988; Gottman & Ringland, 1981). Cyclicity refers to the oscillations between states of affective "on" and "off" detected in the infant's behavior, a pattern resembling activity in the cardiac or brain systems, and synchrony relates to the bidirectional constraints of affective display. Together, the self-organizing and mutual regulatory processes form the ongoing face-to-face dialogue. This integration of predictability and change, the regularity of cyclic oscillations and the openness of social timing, has been proposed as an important contributor to the development of self-regulation vis-à-vis the changing demands of the social world (Fogel, 1993; Schore, 1994).

Individual differences among dyadic systems may be observed on several temporal parameters. First, dyadic systems differ in their ability to settle into a mutually constrained interaction, that is, to achieve global synchrony despite local miscoordinations or external perturbations. Second, such systems differ in their lead–lag relations; some interactions are led by the mother, others are led by the infant, and some may show a simultaneous cross-dependence between the partners' behavior (Cohn & Tronick, 1988). Finally, dyadic systems that are synchronous differ in the time lag to synchrony, the time lag between change in one partner's behavior and the corresponding change in the other partner's behavior. Although few data are available on this parameter, Bettes (1988) and Zlochower and Cohn (1996) found that nondepressed mothers responded nearly twice as fast to their 3-month-olds' vocalizations as depressed mothers, suggesting that when infants are first introduced into the social world, shorter responsivity lags may be optimal.

The hypothesis that affect synchrony may be related to the emergence of self-control is supported by several perspectives. From a psychobiological viewpoint, Schore (1994, 1996) cited evidence suggesting that visual–affective synchrony has an imprinting effect on the development of corticolimbic systems during the critical period of postnatal maturation. Microregulatory sequences of coordination–miscoordination–recoordination occurring during face-to-face play are suggested as affecting the development of the prefrontal cortex, which mediates socioaffective functions. This, in turn, contributes to the emergence of self-regulatory mechanisms during the infant's 2nd year. A similar emphasis appears in Tronick's (1989) emotion regulation model. Tronick and Cohn (1989) found that mothers and infants spent most of their playtime in miscoordinated states, yet most miscoordinated states were corrected at the next step. These oscillations of coordination and miscoordination, inherent in the process of synchrony, are theorized to facilitate the development of self-regulation. From a social theory perspective, Maccoby (1992) underlined the circular, temporally dependent nature of social interactions. Within this framework, several studies have shown that moment-to-moment variations in toddlers' compliance depend on the immediately preceding behavior of the parent (Crockenberg & Litman, 1990; Rocissano, Slade, & Lynch, 1987; Westerman, 1990) and suggested that cycles of compliance-promoting interactions originate in the degree of synchrony or asynchrony experienced in the first social encounters between parents and infants. Support for this proposition comes from Martin's (1981) longitudinal study showing that maternal responsiveness at 10 months, assessed microanalytically with time-series models, predicted child compliance at 24 and 42 months.

The developmental sequence from mutual regulatory experiences to self-regulatory capacities proposed by Kopp (1982) cannot be fully understood without considering temperament and its contribution to variability in self-control. Recently, researchers have focused on the complex interactions between temperament and parenting in accounting for developmental outcomes in general and socialization processes in particular (Kochanska, 1995, 1997; Park, Belsky, Putnam, & Crnic, 1997). Belsky (1997) suggested that temperament affects not only the infant's capacity to self-regulate but also the nature of the relations between parenting practices and developmental outcomes. Difficult infants are theorized to be more susceptible to the availability of specific interactive experiences, making the relations between early parenting behaviors and child outcomes stronger for difficult infants. Kochanska (1997) found that temperament affects which aspects of the maternal style are conducive to child socialization. Gentle maternal discipline tended to promote internalization among fearful toddlers but not among nonfearful children, suggesting that reactive children are particularly sensitive to the combination of the empathetic and regulatory features in the mother's style.

In this study, we examined the relations between mother–infant affect synchrony at 3 and 9 months and self-control, an early form of self-regulation. Self-control was assessed at 2 years and was defined (following Kopp, 1982) as compliance to parental commands and the ability to delay acts on request. We used maternal synchrony with infant affect at 3 months and mutual synchrony (the cross-dependence between maternal and infant affect) at 9 months as the age-appropriate forms of synchrony and as predictors of self-control. This choice was based on the development of mother–infant interaction patterns across the infant's 1st year. At 3 months, synchronous interactions typically occur in the form of infant-leads-mother-follows play. During the second half of the 1st year, as infants develop the capacity to share affect (Emde, Gaensbauer, & Harmon, 1976), social interactions become mutual, and partners learn to adapt to changes in each other's behavior (Feldman, Greenbaum, Yirmiya, & Mayes, 1996). On the basis of the work of Kochanska (1995, 1997) and Belsky (1997), temperament was expected to function as a contributor to self-control and as a moderator of the relations between synchrony and self-control, with stronger associations expected between synchrony and self-control for difficult infants. Children's verbal IQ and a warm maternal disciplinary style, factors that have been shown to predict toddler compliance (Crockenberg & Litman, 1990; Lawrence, 1984), were examined as covariates. Finally, to determine the unique effects of time lag to synchrony, we examined whether shorter time lags to synchrony, particularly at the initial stages of socialization at 3 months, would be related to self-control above and beyond the existence or lack of dyadic synchrony.

Method

Participants

Thirty-six mother–infant pairs were recruited from a list of healthy newborns in well-baby clinics in Jerusalem, Israel. The sample included an equal number of boys and girls and firstborn and second-born infants. Infants were healthy and full-term, weighed at least 2,700 g, and had an Apgar score of 8 or above. Infants were between 12 and 15 weeks of age at the first observation (M = 13.2 weeks, SD = 1.1 weeks), between 36 and 39 weeks of age at the second observation (M = 37.6 weeks, SD = 1.2 weeks), and 24 months old at the third observation (M = 24.3 months, SD = 1.8 weeks). Second-born children had siblings who were 1.5 to 5 years older (M = 2.8 years, SD = 1.6 years) and were healthy, with no history of prenatal or postnatal complications. At the time of the 2-year observation, 2 firstborn children had younger siblings, and 2 mothers were pregnant.

Mothers were between 23 and 36 years of age at the initiation of the study (M = 28.7 years, SD = 2.5 years), had completed an average of 14.2 years of education (SD = 1.1 years), and were currently married to the child's father. All fathers were employed in skilled or semiskilled professions. All families were considered middle class by Israeli standards (Harlap, Davis, Grower, & Prywes, 1977). According to the well-baby clinic records, none of the mothers had suffered serious illness, psychopathology, or serious pregnancy complications. Of the 55 families approached, 41 agreed to participate; 5 composed a pilot sample, leaving 36 families who participated in the study. No significant differences in terms of paternal and maternal education, age, and income or the child's birth order, birth weight, and Apgar score were detected between the families who participated and those who declined.

Of the 36 infants, 33 were observed at 2 years; two families moved abroad, and one could not be located. Thirty-two children were seen at 24 months, and 1 child was seen at 27 months. No significant differences on demographic variables were found between those who returned and those who did not. The final sample included 16 girls and 17 boys, as well as 16 firstborns.

Procedure

At the 3-month and 9-month visits, mothers were invited to a laboratory at a time of day the infants were expected to be fed and rested. Mothers and infants were situated face to face, the infants sitting on an infant seat mounted on a table and the mothers sitting next to the children on an adjustable stool. Mothers were instructed to play freely with the infants as they normally would at home. Ten minutes of play were videotaped by means of a split-screen technique; two cameras fixed on adjacent walls were controlled by a technician in an adjoining room. At 9 months, an additional 10-min toy interaction was videotaped. After the play session, mothers completed a battery of self-report measures. The 24-month visit, scheduled within a month of the children's 2nd birthday, lasted approximately 90 min. Visits began with cognitive assessment. Mothers and children were then observed in several interactive contexts and learning tasks, and mothers completed a battery of self-report measures.

Measures

First-Year Measures

Affect synchrony at 3 and 9 months. Three minutes of mother–infant face-to-face interaction at 3 and 9 months were coded in 0.25-s frames according to the monadic phase coding system (Tronick, Als, & Brazelton, 1980). Monadic phases are response categories specifically created for the analysis of split-second changes in affective states during face-to-face interactions. Phases represent a continuum ranging from negative to positive engagement in the interaction and include the following: protest, avert, object attend, social attend, object play, social play, and talk (Cohn & Tronick, 1987). The monadic phase system uses the widely accepted scaling approach to the assessment of synchrony in which affect is organized on a continuum from negative to positive involvement in play (Beebe & Gerstman, 1980; Cohn & Tronick, 1987; Field, 1994; Lester et al., 1985). This approach enables the definition of synchrony as a match in the direction of change, not necessarily as a match of phase. An example of such synchrony occurs when the infant shifts from avert to social attend and the mother responds with a shift from social attend to social play within a lag of several seconds. The validity of the monadic phase system in relation to discrete-emotion coding systems has been demonstrated (Matias, Cohn, & Ross, 1990; Weinberg & Tronick, 1994).

Coding was performed for 3 min of the interaction (the 2nd, 3rd, and 4th min). Before coding of the entire sample, entire sessions of 10 min were coded in 0.25-s frames for each dyad in the pilot sample (n = 5). Analyses of the pilot sample indicated that 3-month-old infants showed increasing signs of fatigue, fussiness, and gaze aversion after 5 min of play and that during the first moment of interaction, infants often scanned their new surroundings. The most pronounced period of social play occurred between the 2nd and 5th min, once the infant's gaze was focused on the mother's face. Minutes 2, 3, and 4 of the interaction were therefore coded for the entire sample. Two pairs of coders, unaware of the study's hypotheses, observed the tape at normal speed, approximated the time of phase change, and then returned to determine the exact time of phase change while the tape was running in slow motion. Phase changes were rounded to the nearest one fourth of a second. The coding of the mother and her infant was not performed successively to ensure unbiased assessment of their phases. Coders were trained extensively with the monadic phases coding system on the pilot sample until 80% reliability was achieved. Reliability was examined in 20 time series (10 at each age) via a 1-s window. Reliability kappa values for the infant phases were .81 and .82 at 3 and 9 months and .82 for the maternal phases at the two ages.

In line with previous studies using monadic phases (Cohn & Tronick, 1988; Lester et al., 1985), phases were averaged within each 1-s period, resulting in time series of 180 observations for each mother and child. Before the assessment of synchrony, time series were examined for stationarity (consistency of mean and variance across time), and when conditions of stationarity were not observed, series were differenced once. In computing synchrony, we adopted Cohn and Tronick's (1988) technique. First, cross-correlation functions (CCFs) were computed for each dyad at 3 and 9 months. In cases in which no significant cross-correlations were observed on the CCF, further analyses were not carried out. When significant lead–lag relationships were indicated, the autocorrelated component in each time series was partialed before synchrony could be inferred. We estimated the autoregressive component in each time series using separate

ARIMA models (autoregressive integrated moving averages) and recomputed the CCFs on the basis of the series of residuals. ARIMA is a univariate time-domain technique that estimates the autoregressive component in a time series by fitting a best model on the basis of the autocorrelation and partial correlation functions and diagnosing the residuals in regard to lack of autocorrelations (Gottman, 1981).

Three types of synchrony may be observed on the CCF. Positive peaks imply infant-leads-mother-follows relations. Negative peaks suggest mother-leads-infant-follows relations. In cases in which both positive and negative peaks appear on the CCF, mutual synchrony is inferred, suggesting that mother and infant are each responsive to changes in the partner's play. At 3 months, dyads received a score of 1 for maternal synchrony when a positive peak was observed on the CCF and a score of 0 when no such relations were found. At 9 months, dyads received a score of 1 for mutual synchrony when both positive and negative peaks were observed on the CCF; they received a score of 0 otherwise.

Time lag to synchrony. Synchrony can occur at multiple lags, and thus we used the lag in which the largest cross-correlation was observed as our index of time lag to synchrony. Because of the autocorrelated nature of social processes (i.e., behavior is best predicted from immediately preceding events), the largest cross-correlation typically occurs at the first significant lag. At 3 months, the lag to the largest positive peak indicated the time lag to maternal synchrony. At 9 months, because mutual synchrony was indicated by positive and negative peaks, the lag to the largest peak (positive or negative) was used to index the time lag to mutual synchrony. As mentioned earlier, time lag to synchrony indicates the time lag between change in one partner's behavior and the corresponding change in the other partner's behavior.

Infant difficult temperament. Assessments of temperament were based on maternal report and direct observation. For the maternal report, we used the average of the Fussy–Difficult scores from the Infant Characteristics Questionnaire (Bates, Freeland, & Lounsbury, 1979) administered at 3 and 9 months. The Fussy–Difficult factor is the most stable factor of the questionnaire, explains the largest proportion of variance (Bates, 1980), and is theoretically (Hubert, Wachs, Peters-Martin, & Gandour, 1982) and empirically (Goldsmith & Alansky, 1987) related to the negative emotionality construct across taxonomies. In addition, infants' global negative emotional displays in three interactive sessions, one at 3 months and two at 9 months (with and without toys), were each coded on a 5-point scale by different coders and then averaged. Reliability (kappa), measured on a random sample of 12 infants, was .84. The correlation (r) between the averaged observed and the averaged parent-report measures was .54 ($p <$ .001); standardized scores were averaged into an infant difficult temperament composite (α = .71).

Two-Year Measures

Intelligence. Intelligence was measured at 2 years with the Stanford-Binet Intelligence Scale (fourth edition; Thorndike, Hagen, & Sattler, 1986). The test was administered by trained graduate students in psychology. The Verbal Reasoning scale score was used in this study.

Self-control. Self-control was assessed in two interactive contexts intended to tap the two aspects of self-control suggested by Kopp (1982): child compliance and the ability to delay acts on request. Coding, adapted from the work of Kochanska and Aksan (1995) and Crockenberg and Litman (1990), was conducted separately for the two contexts.

Child compliance was examined during a toy pickup task. The pickup task followed a free-play session in which mothers and children played with a variety of toys (three dolls, a tea set, doll clothes and accessories, a doctor set, four puzzles, blocks, a dump truck, two toy phones, plastic animals, and hand puppets). Approximately 40 min into the session, mothers were given a plastic cart and were asked to have the child pick up the toys. Children were given 10 min to complete the task. Sessions were terminated after all toys had been collected or after 10 min.

Coding was performed for each 10-s period. For each 10-s period, one of the following mutually exclusive codes was applied: (a) self-regulated compliance (child performs according to the adult demand without having to be reminded or coerced and with positive affect and enthusiasm; child is cooperative, is totally involved in completing the task, and continues spontaneously with picking up the toys), (b) externally regulated compliance (child generally complies to the maternal request but without enthusiasm, positive affect, or sense of cooperation; child often stops picking up the toys and needs continuous reminders to stay on task), (c) passive noncompliance (child does not pick up the toys, but noncompliance is passive; child is not engaged in an overt conflict with mother), (d) refusal negotiation (noncompliance is accompanied by maternal coercion and child refusal), (e) defiance (noncompliance is accompanied by angry interactions between mother and child), or (f) time out (mother and child take time out from collecting the toys, may move to a different section of the room, or are engaged in other activities). Reliability for the set of codes in the pickup task was examined on six random sessions (347 intervals), and the kappa value for this set of codes was .82. The proportion of self-regulated compliance segments over the entire pickup session was used as our score for child compliance.

The ability to delay acts on request was assessed with a temptation procedure adapted from S. S. Feldman and Sarnat (1986). Toward the end of the session, a research assistant invited the mother and child to a small table set for two with a variety of attractive candies and a bottle of juice. When the child were just about to touch the candies, the assistant mentioned that she forgot to bring cups and asked the child to please not touch the food until she returned. The assistant then left the room for 5 min and returned with the cups. For each 10-s period, one of the following mutually exclusive codes was applied: (a) internal control (child does not touch the prohibited food and waits for the cup, maintaining positive affect and cooperation; child may spontaneously remind himself or herself of the rule, actively diverts his or her attention, and is often engaged in conversation with mother), (b) external control (the child seems to comply and does not lift the candies but may touch them often, needs continuous reminders, and stays preoccupied with the prohibited food; child often resumes touching shortly after being reminded), (c) passive noncompliance (child lifts and eats the food but without overt defiance, negative affect, or negative communication with mother), (d) defiance (noncompliance is combined with angry communication; interaction escalates to yelling, crying, or child pilfering the food from the mother), or (e) time out (child leaves the table). Interobserver reliability for the temptation setting was computed on a random sample of six dyads, and the kappa value for this set of behaviors (180 intervals) was .83. The proportion of internal control segments was used as our measure of the ability to delay acts on request. The proportion of internal control segments from the temptation session and the proportion of self-regulated compliance segments from the pickup task were related (r = .55, $p <$ .001) and were averaged into a self-control composite (α = .72). This composite was used as the dependent variable in the subsequent analyses.

Maternal warm control. The mother's disciplinary style was coded separately for the toy pickup and temptation settings for each 10-s period. Three mutually exclusive codes were used: (a) harsh control (mother uses harsh discipline: physical coercion [e.g., pulling the child's hand from the sweets], yelling, threatening, or humiliating), (b) warm control (mother uses gentle disciplinary strategies, such as suggesting, complimenting, pointing, encouraging, or diverting attention in the temptation setting), and (c) no control (mother does not attempt any discipline). In the toy pickup, no control was indicated by the mother's ignoring the experimenter's request and leaving the toys on the floor or by collecting the toys on her own. In the temptation situation, no control was indicated by the mother's passive acceptance of the child's breaking the rules. Interobserver reliability for the maternal behaviors, assessed on a random sample of six dyads (527 intervals), was .84. The proportion of maternal warm control codes in the two settings was highly correlated ($r = .73$, $p < .001$), and the two scores were averaged into a maternal warm control composite ($\alpha = .87$).

Results

Data analysis was conducted in four steps addressing (a) the development of affect synchrony during the infant's 1st year, (b) the relation of synchrony in the 1st year and self-control at 2 years, (c) the moderating role of temperament in the relations of synchrony and self-control, and (d) the unique relations between time lag to synchrony and self-control. Before data analysis, gender and birth-order effects were examined. No gender effects were found for any of the study variables. Birth-order effects were found for mutual synchrony at 9 months: More second-time mothers and infants engaged in mutual synchrony, $\chi^2(1, N = 36) = 4.35$, $p < .05$. Means, standard deviations, and ranges for all study variables are presented in Table 1.

Affect Synchrony During the 1st Year

ARIMA modeling of mother and infant time series at 3 and 9 months revealed that most time series had significant autoregressive parameters of the first or second order. The significant cross-correlations found at 3 and 9 months accounted for an additional 20.3% and 22.5% of the variance, respectively. At 3 months, 15 mothers (42% of the final sample) showed maternal synchrony with the infant, and 7 infants (18% of the final sample) showed synchrony with the mother. Mutual synchrony was rare at 3 months, observed in only 4 dyads (12% of the final sample). At 9 months, 20 mothers (61% of the final sample) synchronized with the infant (maternal synchrony), and 14 infants (42% of the final sample) synchronized with the mother. Among these 20 mothers and 14 infants, mutual synchrony was observed in 13 dyads.

The prevalence of synchronous interactions of all types was not significantly higher at 9 months than at 3 months, $\chi^2(1, N = 36) = 1.13$, *ns*. However, significantly more dyads engaged in mutual synchrony at 9 months than at 3 months, $\chi^2(1, N = 36) = 5.98$, $p < .05$. Time lag to synchrony did not change significantly with age, $F(1, 35) = 0.45$, *ns*. Longitudinal correlations between maternal synchrony at 3 months and mutual synchrony at 9 months were low, $\phi = .13$, *ns*, and specific forms of synchrony were not stable across the 1st year (the phi correlation between mutual synchrony at 3 and at 9 months was .10, *ns*, and the correlation between maternal synchrony at 3 and 9 months was .20, *ns*).

Maternal synchrony at 3 months and mutual synchrony at 9 months were negatively related to the proportion of negative affect in the infant's time series ($rs = -.35$ and $-.37$ for 3 and 9 months, respectively, $p < .05$). Mutual synchrony at 9 months was negatively related to infant object play ($r = -.39$, $p < .05$) and mother object play ($r = -.37$, $p < .05$) but not to infant social play ($r = .16$, *ns*) or mother social play ($r = .18$, *ns*).

Predicting Self-Control From Synchrony, Temperament, Verbal IQ, and Maternal Discipline

Correlations between the study variables were examined before a predictive model was built. Partial correlations, controlling for birth order, are presented in Table 2.

As can be seen in Table 2, significant longitudinal correlations were found between maternal synchrony at 3 months and mutual synchrony at 9 months and self-control at 2 years. Negative relations were found between infant difficult temperament in the 1st year and self-control at 2 years. Self-control was related to maternal warm control at 2 years.

Hierarchical multiple regression analysis was used to predict self-control. Infant difficult temperament, verbal IQ, and maternal warm control were entered in the first three steps as covariates to examine the unique relations between synchrony and self-control. Next, maternal synchrony at 3 months and mutual synchrony at 9 months were entered according to their developmental sequence. Results are presented in Table 3.

The data presented in Table 3 indicate that infant difficult temperament in the 1st year, maternal synchrony at 3 months, and mutual synchrony at 9 months were each independently related to self-control at 2 years. Maternal warm control was marginally related ($p = .058$) to self-control above and beyond temperament. Verbal IQ did not make a significant independent contribution to the prediction of self-control.

Table 1
Descriptive Statistics

Age and variable	*M*	*SD*	Minimum	Maximum
3 months				
Maternal synchrony[a]	0.42	0.50		
Time lag to synchrony (in s)	2.82	1.30	1.00	7.00
ICQ Fussy–Difficult score	22.67	5.68	11.00	34.00
9 months				
Mutual synchrony[a]	0.69	0.47		
Time lag to synchrony (in s)	2.60	1.50	1.00	9.00
ICQ Fussy–Difficult score	23.30	6.25	13.00	39.00
Negative emotionality (observed)	2.31	1.35	1.00	5.00
2 years				
Self-control[b]	0.28	0.18	0.05	0.70
Maternal warm control[b]	0.41	0.23	0.09	0.76
Verbal IQ	107.77	6.46	88.00	115.00

Note. ICQ = Infant Characteristics Questionnaire.
[a] Proportion of dyads showing synchrony. [b] Mean proportion of time spent in the specified code.

Table 2
Partial Correlations Among Study Variables[a]

Age and variable	1	2	3	4	5	6	7	8
3 months								
1. Maternal synchrony	—							
2. Time lag to synchrony	.74***	—						
9 months								
3. Mutual synchrony	.18	.03	—					
4. Time lag to synchrony	.15	.06	.60***	—				
5. Infant difficult temperament[b]	.07	−.07	.12	.08	—			
2 years								
6. Self-control	.32*	−.14	.56***	.49***	−.34*	—		
7. Maternal warm control	.16	−.05	.12	−.11	−.11	.35*	—	
8. Verbal IQ	.25	−.16	.07	−.06	−.07	.18	−.13	—

[a] Controlling for birth order. [b] Composed of maternal report and observation at 3 and 9 months.
* $p < .05$. *** $p < .001$.

Moderating Role of Temperament

The moderating role of temperament in the relations between synchrony and self-control was examined in two hierarchical multiple regression equations (following Baron & Kenny, 1986). Moderating effects of temperament were not found for maternal synchrony at 3 months and self-control, but significant effects were found for the relation of mutual synchrony at 9 months to self-control at 2 years. The results of this analysis are presented in Table 4.

Results revealed significant independent relations between temperament, synchrony, and their interaction and self-control, thus indicating that temperament functions as a moderator of the relations between mutual synchrony and self-control. The correlations between mutual synchrony and self-control tended to be stronger for the high difficult group ($r = .65$) than for the low difficult group ($r = .25$) when the sample was split at the median (Fisher's $Z = 1.76$, $p < .10$).

Time Lag to Synchrony

Independent relations between time lag to synchrony at 3 and 9 months and self-control were examined in a hierarchical multiple regression. At each age, the synchrony variable (maternal or mutual) was entered before the time-lag-to-synchrony variable to examine whether time to synchrony added unique explained variance above and beyond the achievement of synchronous interaction. Results are reported in Table 5.

Shorter time lags to synchrony at 3 months, but not at 9 months, were independently related to self-control at 2 years when the contribution of maternal synchrony at 3 months was controlled. These results suggest that shorter lags to maternal responsiveness at the first stages of social development are related to a child's self-control in the toddler years.

Discussion

The relations between mother–infant affect synchrony during the infant's 1st year and the emergence of self-control at 2 years were examined. On the basis of Kopp's (1982) model of the antecedents of self-regulation and in line with theoretical positions suggesting that mutual regulatory processes in infancy lay the foundation for later socialization (Emde, 1992; Maccoby, 1992; Schore, 1994; Tronick, 1989), it was expected that the temporal coordination of maternal and infant affect during face-to-face interactions would be related to toddlers' self-control, an early form of self-regulation (Kopp, 1982). Results indicate that maternal synchrony with the infant's affective display and shorter lags to maternal responsiveness during the synchronizing process at 3 months were each related to self-control, suggesting that, at the first stages of social development, both the achievement of synchrony and time lag to synchrony are meaningful to the development of compliance and restraint. At 9 months, the mutual constraint of maternal and infant affect predicted self-control but not time lag to synchrony. These findings are among the first to

Table 3
Predicting Toddlers' Self-Control From Mother–Infant Synchrony, Infant Temperament, Child Verbal IQ, and Mother Discipline

Variable	β	MR	Adjusted *R*	ΔR^2	ΔF	*df*
Infant difficult temperament	−.31*	.34	.06	.09	3.32*	1, 31
Verbal IQ	.22†	.37	.07	.03	1.03	2, 30
Maternal warm control	.22†	.42	.09	.06	2.25†	3, 29
Maternal synchrony: 3 months	.29*	.53	.18	.11	4.43*	4, 28
Mutual synchrony: 9 months	.51***	.74	.47	.25	15.29***	5, 27

Note. Total $R^2 = .54$; $F(5, 27) = 6.54$, $p < .001$; MR = 0.74. MR = multiple *R*.
† $p < .10$. * $p < .05$. *** $p < .001$.

Table 4
Relations of Mutual Synchrony and Infant Temperament to Self-Control

Variable	β	MR	Adjusted R	ΔR^2	ΔF	df
Mutual synchrony: 9 months	.41**	.54	.27	.29	13.23***	1, 31
Infant difficult temperament	−.28*	.62	.35	.10	5.34*	2, 30
Synchrony × Temperament	.34*	.69	.43	.10	5.88*	3, 29

Note. Total $R^2 = .49$; $F(3, 29) = 9.29$, $p = .002$; MR = 0.69. MR = multiple R.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

support the proposed link between face-to-face reciprocity in infancy and the emergence of self-regulatory mechanisms during the toddler years.

Face-to-face interactions, the infant's first participation in a rule-governed social encounter, have been theorized to provide the foundation for the child's social and moral development (Blum, 1987; Emde et al., 1991). Current thought on the interpersonal, mutual, and emotional bases of morality (Day & Tappan, 1996; Kagan, 1987) suggests that the mother's responsiveness to microshifts in the infant's affect facilitates the emergence of moral internalization. Studies within the attachment and social learning perspectives have also shown longitudinal relations between maternal responsiveness in infancy and children's self-regulated compliance (Martin, 1981; Stayton, Hogan, & Ainsworth, 1971). Among the constructs that define the early caregiving system, such as mutuality, reciprocity, and attunement, synchrony highlights the microanalytic, regulatory, and contingent features of early dyadic systems. Several studies have shown that a parental style that integrates positive affect with external regulators promotes socialization and morality in toddlers and older children (Hoffman, 1970; Kochanska, 1997; Maccoby, 1992). Affect synchrony may be an early indicator of this specific style that facilitates the development of self-regulation by combining contingent positive affect and mutual regulation.

Positive affect and mutual regulation are two important features of synchrony that contribute to the development of emotion regulation (Tronick, 1989). Schore (1994) suggested that if the few moments of face-to-face interactions are to affect the development of emotion regulation, interactions need to contain two elements: positive affect and mutual visual regard. The present data indicate that the achievement of synchrony is related to positive affect and mutual gaze. The proportion of negative emotionality in the infant time series was negatively related to mother–child synchrony, suggesting that negative affect may hinder the process of synchrony. Mother and infant object play (dyadic joint attention to objects without visual contact) was negatively related to the achievement of mutual synchrony at 9 months. Thus, face-to-face synchrony may provide a regulatory context wherein infants can achieve high levels of positive arousal, yet the experience is well contained and does not have a disorganizing effect on the child.

In discussing the mutual regulation of affect in infancy, several authors have argued that the microanalytic level of observation best suits the study of self-regulatory and mutual regulatory processes (Schore, 1994; Stern & Gibbon, 1978; Tronick & Cohn, 1989). Gianino and Tronick (1986) suggested that seemingly minor variations in maternal and infant affect or in rates of responsiveness may disrupt the entire process of synchrony and have implications for later development. Thus, microanalysis of maternal and infant affect and assessment of their interdependence by means of time-series analysis may provide a useful window to the study of individual variation in affect regulation. The three temporal parameters of synchrony—achievement of synchrony, lead–lag relations, and time lag to synchrony—are examples of variables in which seemingly minor variations show differential relations to developmental outcomes. For instance, differences in the internal structure of interactions that were led by the mother, led by the infant, or mutually responsive were often extremely subtle. Similarly, differences in latencies to maternal synchrony at 3 months were in the range of seconds, yet they were independently related to self-control nearly 2 years later. Microanalytic assessments of affective processes may therefore serve as early markers of interactions at risk or difficulties in affect regulation that more global assessments may not capture.

The development of synchrony during the 1st year suggests instability on the individual level and continuity on the level of the group. Specific forms of synchrony were not stable between 3 and 9 months. Nor was individual stability found between maternal synchrony at 3 months and mutual synchrony at 9 months, the age-appropriate forms of synchrony at these ages. Yet, the proportion of synchronous interactions of all types remained unchanged across the 1st year, and the two age-appropriate forms of synchrony, maternal and mutual, were equally prevalent at the two

Table 5
Relations Between Time Lag to Synchrony and Self-Control

Variable	β	MR	Adjusted R	ΔR^2	ΔF	df
Maternal synchrony: 3 months	.54*	.30	.06	.09	3.23*	1, 31
Time lag to synchrony	−.45*	.49	.19	.13	5.23**	2, 30
Mutual synchrony: 9 months	.40*	.68	.42	.23	23.77***	3, 29
Time lag to synchrony	.15	.70	.41	.02	*ns*	4, 28

Note. Total $R^2 = .49$; $F(4, 28) = 6.75$, $p = .006$; MR = 0.41. MR = multiple R.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

ages. Maternal temporal matching in the first half of the 1st year and mutual constraint of dyadic behavior in the second half were found to be independent predictors of self-control. These configurations of synchronous interactions possibly tap different mechanisms underlying the development of self-regulation, those of external regulation and those of affective sharing. These mechanisms probably provide independent paths leading from mutual regulatory experiences in infancy to the development of compliance and self-restraint during the toddler years.

Toddlers' self-control was not related to differences in mutual regulatory processes alone; infant difficult temperament contributed meaningfully to variability in self-control and functioned as a moderator of the relations between mutual synchrony at 9 months and self-control at 2 years. Stronger relations between mutual synchrony and self-control were found among the group of difficult infants. These findings support Belsky's (1997) theory regarding differences in susceptibility to rearing experiences among infants of negative and positive emotionality. The data also converge with Kochanska's (1997) results on the moderating role of temperament in the process of socialization. The findings extend previous research in three directions. First, in addition to Kochanska's (1995) findings with toddlers, the results suggest that as early as 3 months of age, when infants first join social interactions, temperament and parenting begin to form independent paths to self-regulation. The separate contributions of temperament and synchrony to the emergence of self-regulation seem to have an earlier onset than has been previously demonstrated. Second, the findings help specify the age at which difficult temperament begins to function as a moderator, in addition to its function as a contributor to self-control. This role seems to emerge during the second 6 months of life, a period when both temperament and parent–child interactions undergo developmental transformations. In the second half-year, infants begin to assume a more equal role in social interactions with the maturation of affective sharing and social initiation (Emde et al., 1976; Feldman, Greenbaum, Mayes, & Erlich, 1997). At the same time, temperamental dispositions consolidate into stable patterns (Belsky, Fish, & Isabella, 1991), and infants enter the stage of "control" (Kopp, 1982), at which they become capable of inhibiting behavior. At that point in development, complex interactions between self-regulatory dispositions and mutual regulatory experiences begin to shape the developmental path leading from external modes of regulation to internal forms of control. Furthermore, the findings point to the specific features of the maternal style that promote self-regulation among difficult infants. The mother's ability to engage in microlevel matching of affect, share control over the interaction with the child, maintain visual contact, and regulate the high positive arousal—the experience of mutual synchrony—may be particularly important in helping less regulated infants achieve self-control.

Finally, the relations between early affect regulation and the regulation of social behavior need replication with larger samples. Several questions remain for future studies. Among them is the comparison of developmental outcomes in cases in which synchrony is disrupted as a result of maternal factors (e.g., maternal depression; Field, 1994) or infant factors (e.g., prematurity; Lester et al., 1985). It is important to know to what extent microlevel synchronous processes are unique to mother–infant dyads or whether they may be found in interactions between infants and fathers or other caretakers. Finally, there is a need to study the specific biological, emotional, and cognitive mechanisms that facilitate the transition from mutual regulation of affective encounters in infancy to the older child's internalization of proper social conduct.

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